PB196779

# TECHNICAL REPORT

## STUDY OF THE POTENTIAL FOR RECOVERING UNREACTED LIME FROM LIMESTONE MODIFIED FLYASH BY AGGLOMERATE FLOTATION

FINAL REPORT

Contract PH 22-68-18

Division of Process Control Engineering
National Air Pollution Control Administration
Department of Health, Education and Welfare

COAL RESEARCH BUREAU
MINERAL INDUSTRIES BUILDING
WEST VIRGINIA UNIVERSITY
Morgantown, West Virginia

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**STANDARD TITLE PAGE FOR TECHNICAL REPORTS**

**1. Report No.** APTD-0613

**2. Govt. Accession No.**

**3. Recipient's Catalog No.**

**4. Title and Subtitle**
Study of the Potential for Recovering Unreacted Lime
from Limestone Modified Flyash by Agglomerate Flotation

**5. Report Date** May 1970

**6. Performing Organization Code**

**7. Author(s)**
Charles F. Cockrell et al.

**8. Performing Organization Rept. No.**

**9. Performing Organization Name and Address**
Coal Research Bureau
Mineral Industries Building
West Virginia University
Morgantown, West Virginia

**10. Project/Task/Work Unit No.**

**11. Contract/Grant No.** PH 22-68-18

**12. Sponsoring Agency Name and Address**
Division of Process Control Engineering
National Air Pollution Control Administration
Cincinnati, Ohio 45227

**13. Type of Report & Period Covered**

**14. Sponsoring Agency Code**

**15. Supplementary Notes**

**16. Abstracts**
The feasibility was studied of recovering the unreacted lime from limestone modified flyash by froth flotation of 200 x 325 mesh fractions. Grades of lime recovered were as high as 80 percent; 47.6 percent grade had been obtained in the preliminary tests. However, as lime grade increased, the recovery of lime decreased. This was attributed to the embedding of small siliceous particles in the lime constituents and the coating of the siliceous coal ash fraction with soluble lime. Tests have indicated that the lime may be liberated by attritional scrubbing and that carbonation and the use of chemical modifiers reduce coating of the siliceous coal ash fractions with lime. Employment of carbonation for pH and soluble lime control, modifiers for zeta potential control, agglomerate (emulsion) flotation and recleaning of the lime concentrates did not improve the yield and grade of lime to permit recovery of a majority of the lime in a highly concentrated form.

**17. Key Words and Document Analysis. (a). Descriptors**
Air pollution
Air pollution control equipment
Sulfur oxides
Combustion products
Limestone
Fly ash
Feasibility
Froth flotation
Particle size
Silicon inorganic compounds
Scrubbers
pH
By-products
Flue gases
Materials recovery

**17b. Identifiers/Open-Ended Terms**
Lime
Flotation
ECMC (Emission Control Minerals Complex)
Emission Control Mineral Complex

**17c. COSATI Field/Group** 13/02, 07/01

**18. Distribution Statement**
Unlimited

**19. Security Class (This Report)** UNCLASSIFIED

**20. Security Class. (This Page)** UNCLASSIFIED

**21. No. of Pages** 267

**22. Price**

FORM NBS-867(1-70)

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APTD-0613

# STUDY OF THE POTENTIAL FOR RECOVERING UNREACTED LIME FROM LIMESTONE MODIFIED FLYASH BY AGGLOMERATE FLOTATION

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FINAL REPORT
May, 1970

Contract PH 22-68-18
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# SUMMARY

As a result of initial promising data obtained on froth flotation of 200 x 325 mesh fractions of limestone modified flyash, extensive studies were undertaken to determine the feasibility of recovering the unreacted lime from limestone modified flyash by flotation separation. Grades of lime recovered were as high as 80 percent in comparison to the 47.6 percent grade obtained in the preliminary froth flotation tests on the 200 x 325 mesh fraction of a limestone modified flyash. However, as lime grade increased, the recovery of lime decreased. This was attributed to the embedding of small siliceous particles in the lime constituents and the coating of the siliceous coal ash fraction with soluble lime. Tests have indicated that the lime may be liberated by attritional scrubbing and that carbonation and the use of chemical modifiers reduce coating of the siliceous coal ash fractions with lime. Employment of carbonation for pH and soluble lime control, modifiers for zeta potential control, agglomerate (emulsion) flotation and recleaning of the lime concentrates did not improve the yield and grade of lime to permit recovery of a majority of the lime in a highly concentrated form. It was indicated that lime grade and yield might be improved through further study; however, the results obtained and the increased interest in wet collection of limestone modified flyash do not warrant further work in this area at this time.

Two other areas of investigation have also shown considerable potential. These are mineral wool production and sulfur recovery; studies will be continued under Contract CPA 70-66.

## Section 1

## INTRODUCTION

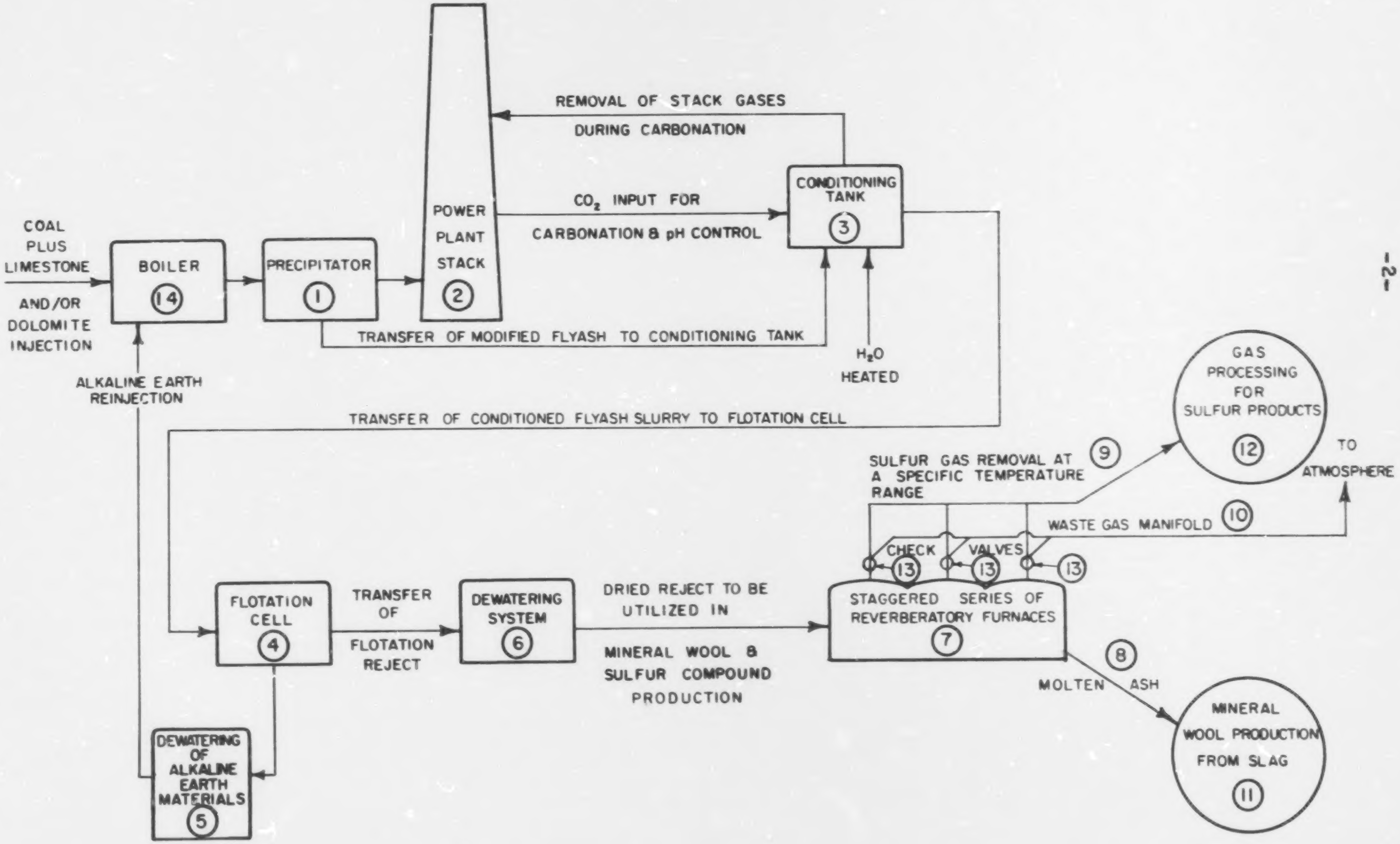
A significant amount of the sulfur oxides emitted to the atmosphere by pollution sources results from coal combustion. (1) The Process Control Engineering Division (PCED) of the National Air Pollution Control Administration (NAPCA) has been developing processes for reducing or eliminating this source of atmospheric pollution. One proposed method that has received considerable attention involves injection of limestone into the boilers of coal fired power stations for calcination and subsequent sorption of the gaseous sulfur oxides. Injection of limestone, however, substantially increases the amount of flyash generated and modifies the chemical and physical properties of the flyash. The quantities generated and the fact that the modified flyash cannot be used in current methods of flyash utilization due to changes in chemical and physical properties could constitute a liability for the limestone injection process. As a part of NAPCA's overall program to determine the feasibility of limestone injection for sulfur oxide control, the Coal Research Bureau was contracted to determine if the potential liability of increased solid wastes due to the generation of large quantities of limestone modified flyash could be converted into an asset to help offset part of the limestone injection process operating costs.

It was observed during initial contract work (2), that such factors as small particle size, sulfur content, solubility and overall chemical properties of the modified ashes precluded concentration of metals or minerals by such common mineral dressing techniques as sieving, specific gravity separation, air classification and magnetic separation. The initial contract work was concentrated on characterizing the physical and chemical properties of limestone-dolomite modified flyashes to determine if fractions or products of a salable nature could be obtained. However, preliminary froth flotation tests on the 200 x 325 mesh fractions of PID dry collected limestone modified flyash showed a recovery of 94.7 percent of the lime in a concentrate of 47.6 percent lime grade. These initial promising flotation results prompted an intensive flotation study for the recovery of unreacted lime. The other most promising methods for utilization during the initial studies were the production of mineral wool and recovery of sulfur gases. These three most promising areas of utilization could be incorporated into a preliminary conceptual plan for an Emission Control Minerals Complex (ECMC) Process (Figure 1) aimed at complete utilization of all fractions of modified flyash. (3)

The ECMC Process would consist of (a) a primary phase of recovery for reinjection of unspent lime from modified flyash-water slurries by carbonation followed by agglomerate flotation and secondary phases of (b) manufacture of heat treated materials, such as mineral wool, from the agglomerate flotation

Figure 1

# THE EMISSION CONTROL MINERALS COMPLEX (ECMC) PROCESS


COAL PLUS LIMESTONE AND/OR DOLOMITE INJECTION
BOILER ⑭
PRECIPITATOR ①
POWER PLANT STACK ②
REMOVAL OF STACK GASES DURING CARBONATION
CO₂ INPUT FOR CARBONATION & pH CONTROL
CONDITIONING TANK ③
TRANSFER OF MODIFIED FLYASH TO CONDITIONING TANK
H₂O HEATED
ALKALINE EARTH REINJECTION
TRANSFER OF CONDITIONED FLYASH SLURRY TO FLOTATION CELL
GAS PROCESSING FOR SULFUR PRODUCTS ⑫
TO ATMOSPHERE
SULFUR GAS REMOVAL AT A SPECIFIC TEMPERATURE RANGE ⑨
WASTE GAS MANIFOLD ⑩
CHECK ⑬ VALVES ⑬ ⑬
FLOTATION CELL ④
TRANSFER OF FLOTATION REJECT
DEWATERING SYSTEM ⑥
DRIED REJECT TO BE UTILIZED IN MINERAL WOOL & SULFUR COMPOUND PRODUCTION
STAGGERED SERIES OF REVERBERATORY FURNACES ⑦
⑧ MOLTEN ASH
MINERAL WOOL PRODUCTION FROM SLAG ⑪
DEWATERING OF ALKALINE EARTH MATERIALS ⑤

rejects and (c) recovery of sulfur values when the rejects are heated. Mineral wool production and sulfur recovery tests were carried out in conjunction with solid waste disposal utilization procedures under study by the Coal Research Bureau for the U. S. Bureau of Mines. (4) Therefore, the work performed under this contract was essentially concerned with the primary phase of recovering the unreacted lime.

All modified flyash samples were subjected to bench scale agglomerate (emulsion) flotation tests as well as support tests such as (a) zeta potential measurements to determine the surface potential of particles of limestone modified flyash and the effect of chemical modifiers on the surface potential, (b) carbonation to determine the reaction of different limestone modified flyashes to this method of solubility control during flotation and (c) thermogravimetric analysis (TGA) to determine the amount of both carbonated particles and agglomerating emulsion associated with the different fractions resulting from flotation separation.

In addition to the extensive tests in these areas, some preliminary investigations were also undertaken on evolution of sulfur oxides from limestone modified flyash at high temperatures under oxidizing conditions as well as lime recovery by agglomerate sieving.

## Section 2

## MODIFIED FLYASH SAMPLES

Modified flyashes used in this study were obtained from the following sources: (a) Detroit Edison Company, St. Clair, Michigan Power Plant; (b) Tennessee Valley Authority, Colbert, Alabama Power Plant; (c) Chevrolet Motor Division Plant, St. Louis Missouri; (d) Union Electric Company, Merrimac Power Plant, St. Louis, Missouri; and (e) Kansas Power and Light Company, Lawrence, Kansas Power Plant.

Details concerning the development, collection and characteristics of the samples supplied by each source follow:

### 2.1 Detroit Edison Company, St. Clair, Michigan

The work undertaken at the St. Clair, Michigan power station was a joint effort by Detroit Edison Company and Combustion Engineering, Inc. to field test the limestone-dolomite injection—wet collection sulfur oxide removal system under development by Combustion Engineering, Inc. In these tests only a small amount of the dust-laden stack gases were diverted to a wet scrubber so that both wet and dry collected modified flyashes were available. When the dolomite tests were completed, a high purity limestone was tested. Thus, it was possible to obtain both wet and dry collected limestone and dolomite modified flyashes. The chemical and physical properties of the limestone dry-collected sample utilized in this study are given in Table 1.

In these tests, the coal and stone were pulverized to approximately 95 percent passing 200 mesh. The crushed stone was injected through the top burner, oriented 30° above the horizontal, of a 325 megawatt Combustion Engineering twin furnace unit. Limestone was fed into the boiler at a rate of approximately 10 tons per hour (180 percent of the stoichiometric requirement).

A combination of electrostatic and mechanical precipitators, rated to be 99.5 percent efficient, was used to collect the dry sample. The dry modified flyashes from each type of precipitator were admixed after collection.

### 2.2 Tennessee Valley Authority, Colbert, Alabama

These limestone modified flyashes were generated at the TVA Colbert, Alabama power station in separate periods of operation when different limestones were being tested. The chemical analyses of the limestone modified flyashes generated by TVA are also shown in Table 1.

### TABLE 1

### CHEMICAL AND PHYSICAL PROPERTIES OF MODIFIED FLYASH AND NORMAL FLYASH USED IN FLOTATION AND RELATED STUDIES

| Source<br>Identification<br>Modifying Stone<br>Mode of Collection | Detroit Edison<br>PID<br>Limestone<br>Dry | TVA<br>$D_1D_2$<br>Limestone<br>Dry | TVA<br>$D_1D_2$<br>Limestone<br>Dry | Chevrolet, St. Louis<br>CM<br>Dolomite<br>Dry | Chevrolet, St. Louis<br>CI<br>Dolomite<br>Dry | Union Electric<br>SLD<br>Dolomite<br>Wet | Kansas Power and Light<br>KPL<br>Limestone<br>Wet | Detroit Edison<br>$DE_1$<br>Unmodified<br>Dry |
|---|---|---|---|---|---|---|---|---|
| Chemical Composition, % (Dry Basis) | | | | | | | | |
| $SiO_2$ | 30.85 | 29.52 | 31.68 | 35.90 | 33.10 | 30.80 | 29.80 | 49.10 |
| $Al_2O_3$ | 13.70 | 13.00 | 14.29 | 14.40 | 11.80 | 14.70 | 6.79 | 16.25 |
| $Fe_2O_3$ | 11.59 | 14.85 | 15.97 | 7.76 | 7.18 | 7.03 | 9.09 | 22.31 |
| $TiO_2$ | 0.68 | 0.53 | 0.56 | 0.71 | 0.65 | 0.64 | 0.42 | 1.09 |
| CaO | 29.79 | 22.55 | 24.94 | 22.97 | 17.92 | 19.56 | 27.13 | 4.48 |
| MgO | 1.49 | 1.56 | 1.49 | 13.93 | 11.45 | 4.77 | 0.97 | 1.00 |
| $Na_2O$ | 1.12 | 0.59 | 0.77 | 0.34 | 0.46 | 0.36 | 0.23 | |
| $K_2O$ | 0.71 | 1.42 | 1.63 | 0.72 | 0.72 | 1.42 | 1.29 | |
| $SO_3$ | 2.20 | 3.73 | 1.95 | 8.05 | 6.95 | 15.38 | 20.25 | 0.73 |
| C | 1.12 | 0.88 | 0.91 | 3.29 | 5.64 | 1.49 | 1.55 | 2.21 |
| Loss on Ignition | 1.03 | 2.00 | 1.30 | 3.79 | 8.34 | 6.13 | 6.01 | |
| Water Soluble Fraction | 22.11 | 21.58 | 9.58 | | | 25.50 | 16.60 | 2.51 |
| Moisture | 0.00 | 0.10 | 0.20 | 0.24 | 0.26 | 98.00 | 99.00 | 0.00 |
| Physical Properties | | | | | | | | |
| Melting Properties, °F | | | | | | | | |
| Initial Deformation Temperature | 2071 | 1740 | 1730 | 1870 | 1720 | 1780 | 1710 | 1702 |
| Softening Temperature, Spherical | 2138 | 2100 | 2120 | 2260 | 2250 | 2140 | 2150 | 2400 |
| Softening Temperature, Hemispherical | 2145 | 2120 | 2130 | 2270 | 2270 | 2150 | 2160 | 2410 |
| Fluid Temperature | 2172 | 2140 | 2140 | 2300 | 2280 | 2160 | 2170 | 2460 |
| Median Particle Size, Microns | 9.30 | 3.80 | 4.40 | 4.30 | 4.20 | 5.10 | 4.00 | 7.10 |

In these tests, the particle size of the injected limestone ranged from 70 percent passing 200 mesh to 95 percent passing 325 mesh. Limestone was injected into the boiler through all sixteen burners by pre-mixing with the coal in proportions approximately equal to 67 percent of the stoichiometric requirement for the 6 percent sulfur content coal being burned. These dry-collected limestone modified flyashes were obtained from standard mechanical cyclone dust collectors which had been designed to remove approximately 70 percent of the particulate matter in the stack gases. In dust collectors of this type, the finer size fractions generally escape to the atmosphere. Thus, the smallest size fractions of modified flyash were not recovered.

### 2.3 Chevrolet Motor Division Plant, St. Louis, Missouri

The injection tests undertaken by Chevrolet Motor Division at their St. Louis assembly plant were performed in a small B & W boiler having a capacity of two tons of coal per hour. Pre-ground commercially available dolomite was tested both by intermixing and by injection above the flame envelope. Physical and chemical characteristics of the resultant modified flyashes produced by this boiler are shown in Table 1.

The CM modified flyash was produced by pre-mixing the dolomite and coal while the CI material was produced by injecting the material above the flame envelope.

In these tests, the dolomite, vended as "dolcito," was injected into the B & W pulverized coal integral furnace type boiler at a rate of 200 percent of the stoichiometric amount required. The dolomite had been pulverized by the supplier to 76 percent passing 230 mesh and 4.4 percent passing 325 mesh. The coal burned during the tests contained 3 1/2 percent sulfur and was obtained from the River King No. 2 mine of Peabody Coal Company and the Sparta Mine of Bell and Zoller Company. The coal was fed into a B & W Type E pulverizer in a ratio of 60 percent River King to 40 percent Sparta where it was pulverized to 70 percent passing 200 mesh prior to combustion. The dry modified flyash was collected in an electrostatic precipitator rated to be approximately 99 percent efficient.

In the initial test, dolomite was admixed with the coal by adding 50 pounds of dolomite every three minutes through the exit port of the weight feeder. A 45 minute delay occurred between the time dolomite was first added and a stable reduction of sulfur dioxide occurred. After the stable reduction occurred, the test was continued for three hours.

In the second test, dolomite was injected from a spider system specifically designed to permit the dolomite to be uniformly sprayed, via six nozzles, into the boiler above the flame envelope at an angle of approximately 45 degrees above the horizontal. This test was also of three hours duration; however, a reduction of sulfur dioxide in the stack gases occurred almost immediately.

## 2.4 Kansas Power and Light Company, Lawrence, Kansas

The tests undertaken at Lawrence, Kansas, were a joint effort by Kansas Power and Light and Combustion Engineering, Inc. on a full-scale, permanent wet scrubbing installation. The scrubbing system is located on the 125 MW, No. 4 Unit and had been operating for approximately one day prior to sample collection. The system used dry injection-wet collection in which limestone, ground to approximately 60 percent passing 200 mesh, was injected at the rate of 110 percent stoichiometric into the 2100°F temperature zone of the furnace. Two separated scrubbing units were incorporated, both of which employed an over-bed recycle system whereby water and modified ash from the bottom of the scrubber were passed to a delay and mixing tank and then recycled by being sprayed above the marble bed in the scrubber. The system used about 3,000 gallons of water per minute of which 700 gallons per minute was obtained from blow down of the cooling tower. The remaining water came from a recycle pond adjacent to the settling pond. Sulfur dioxide was monitored both before and after the scrubber. The coal being burned contained 1,960 parts per million (ppm) sulfur as sulfur dioxide and 760 ppm was sorbed by calcined stone in the dry state. The remaining 1,200 ppm entered the scrubber and 400 ppm were emitted to the atmosphere after scrubbing. Samples for flotation purposes were obtained from the 12 inch I. D. exit pipes leading to the settling pond. The slurry solids were approximately one percent. Physical and chemical analyses of this sample are shown in Table 1.

## 2.5 Union Electric Company, St. Louis, Missouri

Samples of wet collected dolomite modified flyash were also obtained from the Merrimac Plant of Union Electric at St. Louis, Missouri. As was the case at Lawrence, Kansas, a dry injection-wet collection technique was employed. When the samples were taken, one of the two scrubbers was shut down for modification but the water requirement was not reduced. Dolomite of approximately 85 percent passing through 200 mesh size was added at the rate of 60 percent stoichiometric to the 2,000°F temperature zone of the furnace. Approximately 3,000 gallons per minute of water was used, of which 90 percent could be recycled from a clarification system. The slurry concentration of the SLD material, even though it contained twice as much water as normal, was about two percent. Physical and chemical analyses of this sample are also shown in Table 1.

## Section 3

## FLOTATION STUDIES

### 3.1 Introduction

Flotation is a mineral dressing technique for separating physically distinct mineral entities which are generally finer than 28 mesh. Specifically, the objective of froth flotation is to recover valuable metals or minerals by the addition of chemical additives (collectors) which will make the desired mineral system hydrophobic, while permitting the other mineral systems to remain hydrophilic in a water slurry. Usually other chemical additives (modifiers) and pH controls are utilized to aid this action by altering the zeta potential or surface charge (discussed in Section 4) of the systems. Next, the slurry is mechanically or pneumatically agitated to introduce air in such a manner as to cause collisions between the rising air bubbles and the liberated hydrophobic mineral system so that each air bubble levitates one or more of the hydrophobic particles. Other chemicals (frothers) are generally required to assist the collectors in producing a froth which is used to stablize the concentrate so that it may be removed from the surface of the slurry either by displacement or mechanical action. The unlevitated minerals in the slurry (tails) can be either discarded or subjected to further treatment.

Agglomerate flotation differs from froth flotation in that oil-water or water-oil emulsions incorporating both the collector and frother are used to concentrate the desired mineral by causing it to agglomerate or clump together by absorption in the oil media prior to attachment to the rising air bubble.

Flotation separations are usually carried out in a series of basic steps (flotation circuit) whose order can be varied depending on the prevailing circumstances. After the addition of the modifier and collectors, the slurry is usually agitated for a pre-determined period of time (conditioned) in order to allow the chemicals to react with the mineral systems prior to flotation. The slurry is then subjected to the first separation step or rougher separation which produces a concentrate and a tail. The concentrate can then be refloated or recleaned (utilizing more chemical additives if desired) as many times as necessary to obtain the desired concentration. Further flotation of the tails or unlevitated mineral systems to obtain any of the desired mineral missed in prior separations is called scavenging.

The results of flotation separations are usually given in terms of grade and yield. Yield is a percentage measure of the amount of desired mineral removed from the feed, eg, reporting in the concentrate. Grade is a percentage measure of the purity of the concentrate in terms of the desired mineral. For example, the 47.6 percent grade and 94.7 percent yield found during the preliminary flotation tests indicated that 94.7 percent of the lime in the feed material was recovered in a concentrate that was 47.6 percent lime.

### 3.2 Purpose of the Flotation Studies

The intensive flotation studies were undertaken to (a) determine the feasibility of recovering major portions of lime from dry collected limestone modified flyash, (b) determine the feasibility of incorporating the rejects obtained from the flotation as a raw material for mineral wool production and sulfur recovery in order to utilize all fractions of modified flyash and (c) to expand the technology developed to all types of modified flyash.

### 3.3 Flotation Results

The flotation data obtained are given in Appendix A. For convenience, typical data have been abstracted and presented in Table 2. As shown in Table 2, concentrates in excess of 80 percent lime were obtained; however, the grade (54.66) and yield (34.99) of Test 85 are more representative of grades and recoveries usually obtained.

The first phase of flotation work sought to upgrade lime yield and grade through a series of empirical tests to identify variables that might affect yield and recovery. The major findings were that process results could be improved by (a) employment of agglomerate flotation, rather than conventional froth flotation to more effectively separate the very fine particles of modified flyash and (b) carbonation of the modified flyash-water slurries for the reduction in the amount of soluble lime present in the flotation water and subsequent pH control of the slurry. Other operational variables which affected process results were (a) percent solids in the slurry, (b) flotation machine rotor speed, (c) carbonation time (a measure of the rate of carbon dioxide injection and the capacity of the flotation slurry to absorb carbon dioxide), (d) slurry pH after carbonation, (e) type of promoter (collector), frother and modifier, (f) slurry conditioning time and (g) length of time of the flotation separation.

The second phase of work represents efforts to further improve lime grades and yields through adjustment of the factors identified in the first phase. A series of 16 factorially designed flotation tests were also performed during the second phase. The tests had the objective of improving lime grades and yields through determination of the effect of change of (a) emulsion addition rate, in pounds per ton, (b) agglomeration (conditioning) time after emulsion addition, (c) impellor rotor speed during flotation separation and (d) rosin content of the tall oil used in the agglomerating emulsion.

### 3.4 Experimental Flotation Separations

Experimental flotation separations for modified flyash consisted of preconditioning, modifier addition, carbonation, agglomerating emulsion addition, separation of a lime rich fraction by aeration and levitation and recleaning both the levitated concentrates and unlevitated tails.

## TABLE 2

### TYPICAL RESULTS OBTAINED FOR LIME RECOVERY BY AGGLOMERATE FLOTATION OF LIMESTONE MODIFIED FLYASH
(Abstracted From Appendix A)

| Table | Test No. | % CaO of Limestone Modified Flyash | % Grade CaO in Agglomerate Flotation Concentrate* | Calculated $CaCO_3$ Equivalent | % CaO Recovered | Ratio of Enrichment |
|---|---|---|---|---|---|---|
| 1A | 79 | 22.55 | 51.98 | 93.0 | 18.32 | 2.31 |
| 3A | 85 | 29.79 | 54.66 | 97.9 | 34.99 | 1.85 |
| 8A | 94 | 29.79 | 32.25 | 57.7 | 74.75 | 1.08 |
| 16A | 115 $CC_2$ | 29.79 | 81.45 | 145.8 | 4.04 | 2.73 |
|  | 115 | 29.79 | 39.62 | 53.0 | 30.08 | 1.33 |

*Based on Dried and Ignited Sample

Flotation separations were performed in a WEMCO Fagergren Mineral Master flotation machine of 600 gram capacity manufactured by Western Machinery.* The following observations were made concerning the separations:

3.41 Preconditioning. Modified flyash-water slurries were conditioned as an initial step by intensively mixing water, modified flyash and a collector in the flotation cell to insure complete wetting as well as to assure proper collector attachment. From the flotation data obtained, it was indicated that conditioning time was important and that increased conditioning time was beneficial in improving lime grade. No improvement in yield was indicated.

During conditioning, the lime particles were softened by the water and abraded by collisions. This increased the already high solubility of lime in water and required additional carbon dioxide to control the pH. However, increased conditioning time was found to liberate relatively pure quantities of lime by the abrasive action on the softened particle. This was indicated in Test 115 (Table 2) in which an increase in conditioning time from the normal 15 minutes to one hour was partially responsible for the increase in grade from 29.79 percent to 81.45 percent in the second cleaner concentrate ($CC_2$).

As an alternative to increased conditioning time, tests were undertaken to determine the feasibility of accelerating particle breakdown by attritional scrubbing of high solid (80 percent) slurries prior to flotation. Some particle breakdown was observed microscopically; however, further microscopic analysis and flotation testing would be required to determine the full effect of particle breakdown by this method.

3.42 Modifier Addition. The purpose of adding chemical modifiers prior to the addition of the agglomerating emulsion is to selectively alter the zeta potential (surface charge) of the lime fraction to permit selective adsorption of the collector by the lime. A wide variety of di- and trivalent compounds were tested because the effectiveness of a modifier generally increases with increased valence and decreased ionic radius due to increased adsorptive capacity of the smaller ions by the mineral. Additions to the modified flyash-water flotation slurries of divalent ferrous ammonium sulfate (FAS), usually at one pound per ton (PPT), were found to be the most effective modifier. The effects of modifiers on the surface charge were determined by zeta potential measurements and are discussed in detail in Section 4.1.

3.43 Carbonation. The purpose of carbonating the modified flyash water flotation slurries was to decrease the amount of undesirable water soluble lime (solubility 1.31 grams per liter) by formation of essentially insoluble calcium carbonate (solubility 0.014 grams per liter). In agglomerate flotation tests at 5.4 percent solids up to 35 percent of the lime reported in the water if the slurry was not carbonated. However, carbonation of flotation slurries of the same solids concentration reduced the amount of soluble lime five-fold.

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*Trade names are used to facilitate understanding and do not imply endorsement of any particular piece of equipment or manufacturer.

Carbonation was also found to be necessary for pH control. Carbonation was found to effectively lower the slurry pH from 12 to 13.5 to a more acceptable range for flotation separation of 6.5 to 9. Zeta potential data, reported in Section 4.1, showed that such a pH adjustment was necessary to achieve a suitable difference in surface charges of various modified flyashes even with the addition of chemical modifiers. Carbonation was selected in place of such seemingly appropriate mineral acids as hydrochloric acid because (a) lowering the pH was not possible with practical quantities of hydrochloric acid because the formation of highly soluble calcium chloride (745 grams per liter) would result in a decrease of available lime for flotation and (b) carbonation precipitates any additional lime that might be brought into solution by equilibrium dynamics for a period of several minutes to an hour or more which allows sufficient time for the flotation separation.

The reactions involved in carbonation of lime are well known and would proceed as follows:

$$Ca + H_2O \qquad Ca(OH)_2 \quad . \qquad (1)$$

When carbon dioxide is injected,

$$Ca(OH)_2 + CO_2 \qquad CaCO_3 + H_2O \quad . \qquad (2)$$

Any excess carbon dioxide yields carbonic acid by the equation

$$CO_2 + H_2O \qquad H_2CO_3 \quad . \qquad (3)$$

The formation of extremely soluble calcium bicarbonate by the reaction

$$CaCO_3 + CO_2 + H_2O \qquad Ca(HCO_3)_2 \qquad (4)$$

was not found to be a problem.

Chemical analysis of the flotation water never indicated the presence of excess calcium after carbonation as might be predicted by the above equation. While no tests were run, the absence of bicarbonates might be attributable to the presence of unreacted lime in the center of particles coated with calcium carbonate which came into solution slowly and took up any excess carbonic acid.

After the initial requirement for carbonation was established with one limestone modified flyash (PID), a systematic study was undertaken to determine the mechanisms involved. These studies are reported in detail in Section 4.2.

3.44 Emulsion Composition. Initial emulsion composition was 50 percent water, 22.5 percent tall oil collector, 25 percent fuel oil dispering agent and 2.5 percent sodium akylaryl sulfonate (SAAS) frother and was within the general range used for flotation of other minerals. (5) Subsequent tests with tall oils of different rosin acid contents showed that more than 28 percent or less than about 15 percent rosin acid content sharply reduced the grade of lime that could be recovered. This factor was included in factorial tests (Table 8A, Appendix A) and it was indicated that tall oil containing 22 1/2 percent rosin acid would be best for the emulsion. Later flotation tests in which the amount of SAAS was varied from 0.5 to 2.5 percent showed that about 2.0 percent SAAS resulted in the best emulsion composition for optimum flotation separation.

3.45 Flotation Separation. Agglomerate (emulsion) flotation separations were made by inducing air as very small bubbles to the bottom of the flotation cell to levitate the lime rich fraction to the surface for mechanical removal. The initial rougher separations were generally of one to ten minutes duration.

Staged rougher separations (Test 85, Table 2) showed that the grade decreased sharply after five minutes.

Agglomerate (emulsion) flotation was used, rather than conventional froth flotation, to more effectively separate the very fine particles of modified flyash. After numerous tests in the first stages of flotation testing, it was indicated that froth flotation would not be as effective in lime recovery from unsized modified flyash as it was with the sized (200 x 325 mesh) flotation feed. In agglomerate flotation, the conventional organic flotation reagents for collection and froth generation are mixed with oil, generally a low grade fuel oil, and then emulsified with water. When added to the modified flyash-water flotation slurries, the ultra fine carbonated calcium rich particles are preferentially absorbed in the oil rich phase of the emulsion.

3.46 Recleaning. The initial rougher concentrates (RC) were recleaned by refloating for improvement of lime grades. The recleaning procedures tested involved both recleaning without recycling of the unlevitated tail products and with recycling. The purpose of recleaning without recycling was to obtain maximum grades and highest possible ratio of enrichment (ratio of percent lime in fraction to percent lime in the feed) whereas recycling was employed as a means of improving lime yields.

Data from tests (shown in Table 3) have been abstracted from Appendix A to show typical (Tests 85 and 11) results obtained with and without recycling the unlevitated tail products when recleaning the rougher concentrates (RC). For Test 85, grade, recovery and enrichment values were respectively, 47.87 percent, 42.80 percent and 1.61 for 1 RC; 26.44 percent, 16.85 percent and 0.89 for 2 RC and 20.97 percent, 30.05 percent and 0.70 for 3 RC. The first fraction (1-$CC_1$) obtained on recleaning for 1 RC yielded a product containing 60.29 percent lime but recovery, in terms of total lime, decreased to 24.62 percent. The ratio of enrichment showed a favorable increase to 2.02. The second recleaning fraction (1-$CC_2$) was obtained by raising the flotation machine impellor speed from 1100 to 1700 rpm and a lime grade of 44.76 and 10.37 percent lime recovery was obtained. Recleaning 2 RC and 3 RC showed little improvement in lime grade and might be attributed to the fact that most of the emulsion had been removed from the cell with 1 RC.

The low lime yields and the fact that most of the emulsion was removed in the initial stages of the rougher separation led to recycling the unlevitated tail products from recleaning the rougher concentrates. These cleaner tails were combined with the rougher tails (RT) for further cleaning. To maintain sufficient froth throughout the recleaning operation, the emulsion was added in stages. Generally, one-half the emulsion was added prior to the rougher separation and the rest at various stages of recleaning.

Test 111 is an example of such a test with both recycling the unlevitated tails and staged emulsion addition. In Test 111, 10 pounds per ton (PPT) emulsion was added for the rougher separation, five PPT was later added for the flotation of the total cleaner tails (Scavenger) and five PPT was finally added for recleaning the tails (RT and ST). The cleaner concentrate ($CC_2$) obtained by cleaning the RC twice was 49.47 percent lime with 29.41 percent recovery.

## TABLE 3

## AGGLOMERATE FLOTATION OF LIMESTONE MODIFIED FLYASH PID WITH AND WITHOUT RECYCLING THE UNLEVITATED TAILS

(Abstracted From Appendix A)

### Recleaning Without Recycling

| Table | Test No. | Emulsion Addition PPT | Fraction | Grade CaO % | Yield Recovered % | Ratio of Enrichment |
|---|---|---|---|---|---|---|
| 3A | 85 | 140.75 | 1-RC | 47.87 | 42.08 | 1.61 |
| | | | 1-CC$_1$ | 60.29 | 24.62 | 2.02 |
| | | | 1-CC$_2$ | 44.76 | 10.37 | 1.50 |
| | | | 2-RC | 26.44 | 16.85 | 0.89 |
| | | | 2-CC$_1$ | 28.50 | 10.51 | 0.96 |
| | | | 2-CC$_2$ | 30.46 | 7.92 | 1.02 |
| | | | 3-RC | 20.97 | 30.05 | 0.70 |
| | | | 3-CC$_1$ | 21.02 | 29.21 | 0.71 |
| | | | 3-CC$_2$ | 21.08 | 28.66 | 1.00 |
| | | | Total RC | 30.26 | 89.71 | 1.02 |
| | | | Total CC | 54.66 | 34.99 | 1.17 |

### Recleaning With Recycling

| Table | Test No. | Emulsion Addition PPT | Fraction | Grade CaO % | Yield Recovered % | Ratio of Enrichment |
|---|---|---|---|---|---|---|
| 12A | 111 | 10.00 | RC Tails Recycled to Scavenger Float--No Data Obtainable | | | |
| | | | CC$_1$ Tails Recycled to Scavenger Float--No Data Obtainable | | | |
| | | | CC$_2$ | 49.74 | 29.41 | 1.67 |
| | | 5.0 | SC (CT$_1$ + CT$_2$) | 39.72 | 20.22 | 1.33 |
| | | 5.0 | TC$_1$ (RT + ST) Recycled--No Data Obtainable | | | |
| | | | TC$_2$ | 27.39 | 15.77 | 0.92 |
| | | | Total CC | 39.01 | 65.40 | 1.31 |

When the total CC from each test is compared, it is evident that substantially more of the lime was recovered in Test 111 but the lime grade was lowered by 15.65 percent with 120 PPT less emulsion. The effect of recycling is best illustrated when the scavenger concentrate is compared with the second float fraction of 1 RC of Test 85. The recleaning with recycling resulted in an SC of 39.72 percent and 20.22 percent recovery as compared to 44.76 percent grade and 10.37 percent recovery for 1 RC of Test 85.

In summary, the recleaning tests showed that recycling the unlevitated tail products, with staged emulsion addition, would be more applicable because yield could be increased without greatly reducing grade.

## 3.5 Factorial Design Flotation Tests

The purpose of the factorial design experiment was to optimize the factors believed to exert the greatest influence on the lime grade and yield. These factors were chosen as a result of information obtained from previous flotation tests. The factors studied were emulsion addition rate (in pounds of emulsion per ton of ash), conditioning or agglomeration time, flotation cell impellor speed and tall oil rosin content. The factorial design, standard operating conditions and results are given in Table 8A, Appendix A.

Since one of the problems attendant to flotation separations was low lime recovery, a different method of separation and recleaning was incorporated in the standard operating conditions of the factorial design experiments. In the factorial tests, emphasis was placed on shorter periods of rougher separation (4 minutes versus 10 or more minutes) followed by cleaning of the combined unlevitated tail products.

The standard operating conditions, with one exception, were those conditions found in previous flotation tests and zeta potential determinations to give the highest grades of lime. Make-up water for cleaning and recleaning stages, however, was recycled from previous flotation steps, when possible, to reduce the total water volume to a workable level. The recycling of water between stages was found to have no noticeable effect on grade and yield.

The levels of the factors were within the range of normal separation conditions except for the emulsion addition rate which was lowered in an effort to determine what lime grades and yields could be obtained with more economical additions of emulsion.

The responses measured were grade and yield. Since either grade or yield may normally be improved at the expense of the other, the product of grade times yield was also calculated with the objective of maximizing this function as a means of obtaining a compromise between the divergent correlations that would be expected for grade versus yield. The grades and yields given in Table 8A, Appendix A, were obtained from weighted averages for grades and yields for $CC_2$, SC and $TC_2$.

The factorial experiment indicated that:

1. Rosin content and impellor speed were significant at the 95 percent confidence level for yield.

2. Second, third and fourth order interactions accounted for all other assignable variance. There was no variance accounted for in the grade times yield data.

3. Rosin content for the tall oil was the most important variable accounting for 40 percent of assignable variance for the yield data. Increases in grade might be achieved through increased rosin content; however, rosin content should be decreased to improve lime yield. Staged emulsion additions might partially satisfy these opposing conditions.

4. Emulsion addition rate should be increased to improve yield but decreased to improve grade.

The presence of substantial higher order interactions and the low variance accountability indicated that the data could not be used with good reliability to predict results of future tests outside the range of the experiment. Further, the tests indicated that there were probably other significant factors which were not controlled during the factorial tests.

Tests 108 through 115 were undertaken to test the validity of conclusions within the area of experimentation and to determine how far the experimental results might be extended. Tests 108 and 110 were performed at the midpoint of the factorial design (eg, 80 PPT emulsion addition rate, 7.5 minutes conditioning, 1425 RPM and 23 percent rosin) to test the practicability of staged emulsion additions. In these tests 40 PPT emulsion was added to the rougher separation and 20 PPT to both the cleaner tail separation and the rougher tail separation. The grades and yields obtained were 31.39 percent and 76.77 percent respectively for 108 and 28.96 percent and 62.20 respectively for 110. Test 108 was in good agreement with the predicted values and tended to confirm the validity of the experimental equations within the range of the experiment. However, the poor results obtained with 110, which was run to confirm the data of Test 108, indicated that other factors were affecting the grade and yield results. A review of the carbonation data revealed that the pH values of Tests 95 and 110, both of which gave poor yields and grades, rose rapidly during conditioning and were higher than any other tests during rougher separation, rougher concentrate cleaning, cleaner tail cleaning and rougher tail cleaning. The cause of this rapid increase in pH was not determined; however, it did point out the necessity of closer monitoring of carbon dioxide input.

Test 109 was based on the steepest ascent calculations from the factorial design data. Factors under study were set as follows:

80 PPT Emulsion Addition Rate (staged addition)
3.5 Minutes Conditioning Time
1681 RPM Rotor Speed
15 Percent Tall Oil Rosin Content .

The weighted average for $CC_2$, SC and $TC_2$ resulted in 32.25 percent lime grade and 76.22 percent recovery. Agreement between the experimental values and steepest ascent calculations was not good. The observation during this test that the agglomerate was more voluminous with 15 percent rosin and the observation during Test 110 that there were very little tails when the rougher concentrate was recleaned indicated that further gains might be made by lowering the emulsion addition rate. Thus, Test 111, shown in Table 3, utilized only one-fourth the emulsion of Tests 108 through 110 so that the effect of the reduced emulsion could not be masked. Overall lime grade for a weighted average of $CC_2$, SC and $TC_2$ was 39.01 percent with a recovery of 65.40 percent. The $CC_2$ fraction was 49.74 percent grade and 29.41 percent recovery. The rougher concentrate in Test 111 was very light in color and substantial tails were washed out during cleaning. There did, however, appear to be excessive froth so that subsequent tests, numbers 112 through 114, were concerned with determining a better level of SAAS as well as verifying Test 111 and making carbon dioxide measurements during carbonation. SAAS was cut from 2.5 to 0.5 percent of the emulsion in Test 112. The froth was insufficient and the sample was not submitted for chemical analysis. SAAS was increased to 1.5 percent of the emulsion in Test 113 and the carbon dioxide was injected slowly enough to keep the initial pH dip to a minimum. The conditions for Test 113 that varied from standard conditions were:

20 PPT Emulsion Addition Rate
3.5 Minutes Conditioning Time
1700 RPM Rotor Speed
15 Percent Rosin
1.5 Percent SAAS in Emulsion .

The overall lime grade and yield was 41.61 and 54.95 percent respectively with the $CC_2$ fraction being 52.24 and 14.77 percent respectively. The froth still appeared to be deficient.

A flowmeter was obtained and installed for Test 114 and the carbon dioxide flow measured in order to determine the effect of the rate of carbon dioxide injection on pH stability. The test conditions were:

20 PPT Emulsion Addition Rate
3.5 Minutes Conditioning Time
1700 RPM Rotor Speed
15 Percent Rosin
2.0 Percent SAAS in the Emulsion
1.0 CFM Carbon Dioxide Injection Rate .

The overall lime grade and yield for Test 114 were 39.31 and 58.44 percent respectively with the $CC_2$ fraction containing 49.53 percent lime with a yield of 19.72 percent of the lime. The pH exhibited the same stability found in other tests and the froth appeared to be adequate. The data obtained for both Tests 113 and 114 appeared to confirm the conditions of Test 111 as being advantageous over the previous higher rates of emulsion addition.

### 3.6 Summary

Values were found for the flotation separation parameters that improved lime grade and/or yield. Some additional improvement in grade and yield was made and the amount of emulsion drastically reduced as a result of the factorial design study. However, acceptably higher grades and yields of lime were not consistently achieved and it must be concluded that further substantial bench scale study would have to be undertaken to obtain further improvements in grade and yield.

## Section 4

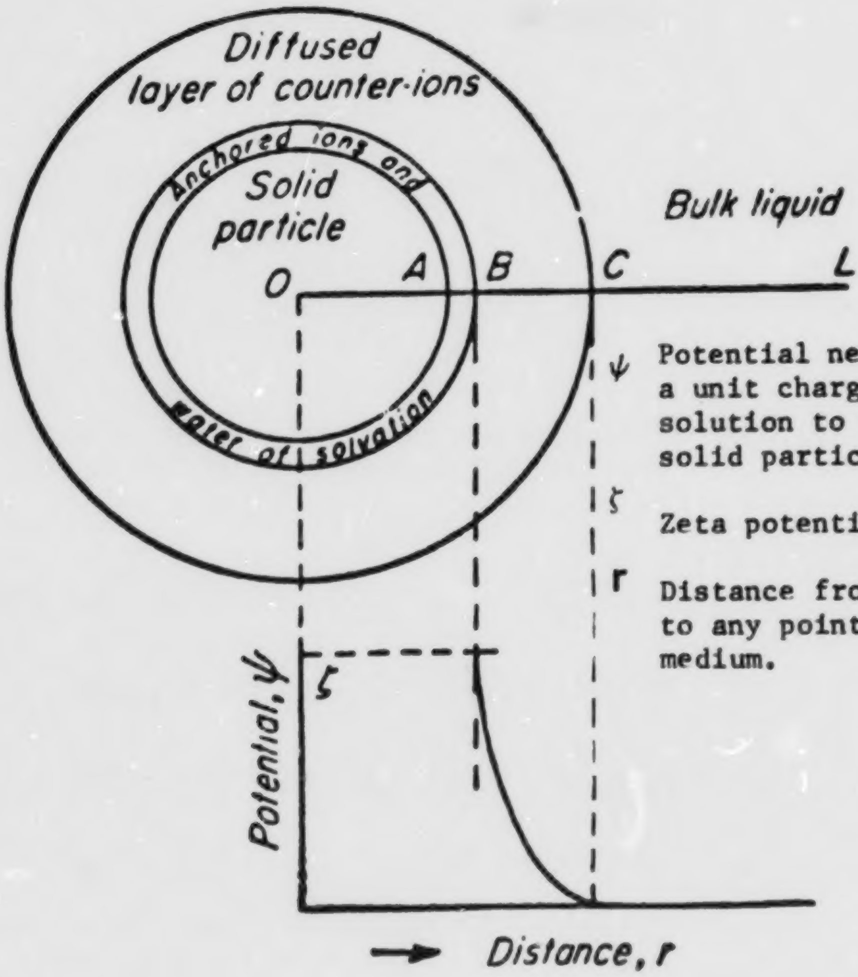
## SUPPORTIVE FLOTATION STUDY TESTS

Zeta potential, carbonation, thermal-gravimetric and microscopic analyses tests were undertaken to determine the best approach for upgrading flotation lime grades and yields. In addition, it was desired to develop technology for the expansion of flotation recovery of lime to a variety of modified flyashes.

### 4.1 Zeta Potential Studies

Zeta potential (ZP) studies were undertaken as a means of determining the surface chemical charge of constituents of limestone modified flyash after preliminary ZP measurements. (6,7) Numerous tests, undertaken in the initial phase of flotation separations, showed that pH adjustment, through carbonation of the flotation slurries alone would not be sufficient to alter the surface charge for separation of relatively pure lime. Specific conductance (SC) data, obtained in the course of making ZP determinations, was also found to be a convenient way of determining the amount of water soluble material remaining in solution during and after carbontion.

The ZP of a material is the charge exhibited by a collodial particle and its hydration sphere with respect to the bulk of the solution in which the particle is suspended. This is shown diagramatically in Figures 2 and 3. Figure 2 illustrates the environment encountered by a colloidal particle in suspension and indicates the region of space that zeta potential covers. The zone OA represents a solid spherical particle of small size having a definite charge associated with it, zone AB represents both a layer of solvation molecules and a layer of anchored ions of opposite charge to that of the particle and is sometimes called the Stern layer or plane. These ions are anchored by the attractive forces of oppositely charged particles. Zone BC, the Gouy layer, represents a diffuse layer of counter ions having the same charge as the solid particle and are the counter ions of the anchored ions. Zone CL represents the bulk of the solution in which the particle is suspended. The distance from O to L is essentially infinite with respect to the size of the particle. If a unit charge were brought from L to C, the potential necessary would be small; however, it would increase as the charge was brought from C to B due to the influence of the Gouy layer containing counter ions. The potential at point B is called the zeta potential and is illustrated on the graph at the botton of Figure 2. Figure 3 gives a better picture of the electrical phenomena occurring in the two layers. In this figure, the solid spherical particle is represented by region A and has a negative charge resulting from negative ions at the particle surface called potential determining ions which may be part of the particle itself. Region B illustrates the anchored ions, those directly influenced by the potential determining ions,

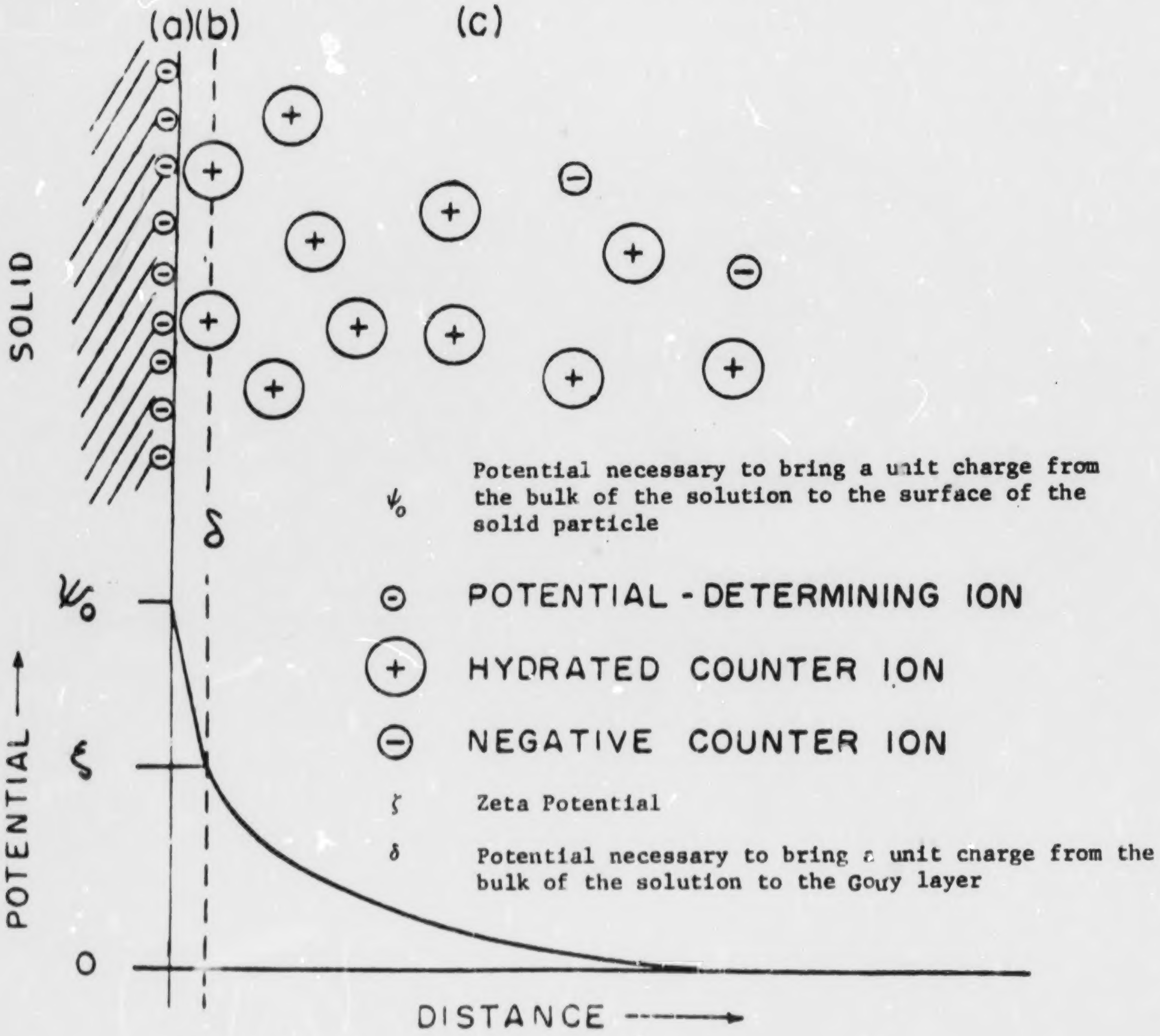

Diffused layer of counter-ions
Anchored ions and water of solvation
Solid particle
Bulk liquid
O
A
B
C
L
$\zeta$
Potential, $\psi$
Distance, r

$\psi$ Potential necessary to bring a unit charge from the bulk of the solution to the surface of the solid particle.

$\zeta$ Zeta potential

r Distance from the solid particle to any point in the surrounding medium.

Figure 2 Relationship of potential to distance from surface of shear for a spherical colloidal particle.
(Gaudin, A. M., Flotation, 2nd ed., McGraw-Hill, New York, (1957), 100)


(a)(b)
(c)
SOLID
POTENTIAL ⟶
$\psi_o$
$\zeta$
$\delta$
0
DISTANCE ⟶
⊝ POTENTIAL - DETERMINING ION
⊕ HYDRATED COUNTER ION
⊖ NEGATIVE COUNTER ION

$\psi_o$ Potential necessary to bring a unit charge from the bulk of the solution to the surface of the solid particle

$\zeta$ Zeta Potential

$\delta$ Potential necessary to bring a unit charge from the bulk of the solution to the Gouy layer

Figure 3 Schematic representation of the structure of the double layer and potential distribution in the double layer in electrolyte solutions.
(Furenstenau, D. W. (ed.), *Froth Flotation*, AIME, New York, (1962), 179)

and held near the immediate surface of the particle. Also shown are counter ions (ions of opposite charge to that of the particle) surrounding the particle a short distance away. In this figure, the ions are considered to be hydrated. Region C contains both counter ions and counter-counter ions, the latter having the same charge as the particle. The zeta potential is again defined as the potential necessary to bring a unit charge from the bulk of the solution to point B, the Stern layer.

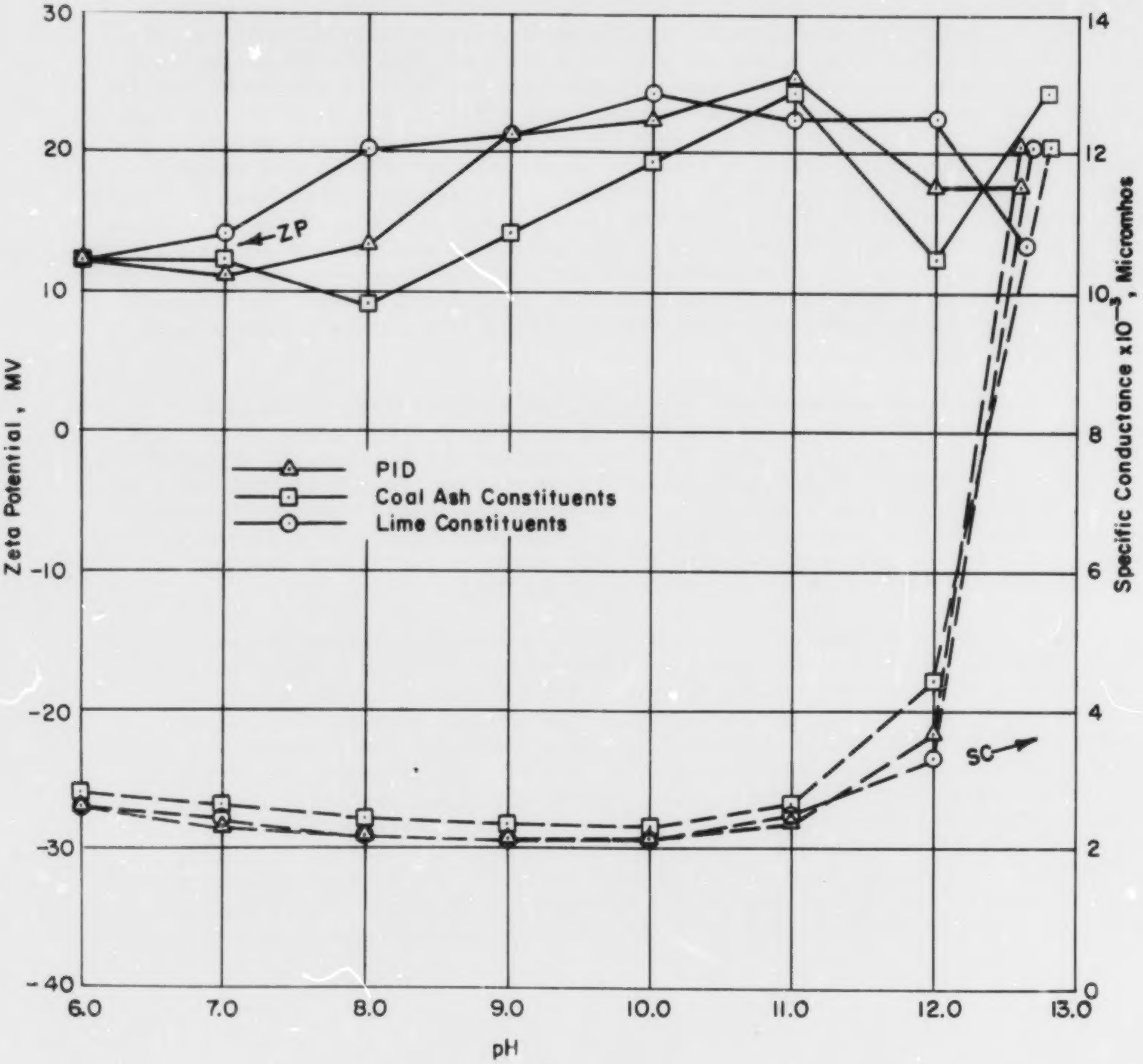
All ZP and SC data obtained for the modified flyashes are given in Appendix B. Typical ZP and SC curves are shown in Figure 4. The ZP and SC for whole modified flyashes and both their coal ash and lime constituents were determined. The ZP and SC values for lime constituents of modified flyash are not true values because pure fractions of the lime constituent could not be obtained. It was found, however, that fractions high in lime could be separated by a combination of magnetic and specific gravity separation and that the ZP of these non-magnetic, 2.96 specific gravity float fractions was a good measure of the ZP of the lime constituent. In the case of wet collected modified flyashes, the parent flyash was not available to determine the ZP of the coal ash constituent; therefore, the magnetic fraction was used to determine the ZP of the coal ash constituent and the nonmagnetic fraction was used for the lime constituent. As a result of the inefficiency of the magnetic and specific gravity separations, it was necessary to separate large amounts of modified flyash to obtain small quantities of the lime fraction. The scarcity of samples precluded separation of sufficient amounts of the lime fraction for all ZP tests. It was found that the parent modified flyash curve generally represented a resultant curve of the lime and coal ash constituents and that valid interpretations of the ZP data could be made without determining a lime constituent curve. For this reason, only the coal ash and parent modified flyash constituent curves were made for some tests.

In making ZP determinations, the effect of concentration of soluble electrolytes was determined for modified flyash PID at the natural pH of 33 percent solid-water slurries. The data obtained showed that the ZP of the materials present in modified flyash is negative at levels of high dilution where there are only small amounts of soluble electrolytes present. However, at the higher solids concentration that would be encountered in a flotation cell, the solution electrolytes make all constituents positively charged through surface adsorption of postively charged ions.

As indicated in Figure 4, there were only small differences in the ZP of the coal and lime constituent of modified flyash. This unfavorable situation existed because of absorption of soluble ions from the slurry on both the coal ash and lime constituents. Therefore, modifier tests were undertaken to determine the effect of chemical additions for preferential absorption on either the lime or coal ash constituents to permit selective flotation collector absorption in the flotation slurry. Postively charged modifiers tested were trivalent aluminum as aluminum potassium sulfate, aluminum sulfate and aluminum chloride; trivalent iron as ferric chloride; and divalent iron as ferrous ammonium sulfate (FAS). Anionic modifiers tested were trivalent phosphate as phosphoric acid and divalent sulfide as sodium sulfide. One modifier test was also run with amphoteric starch.

FIGURE 4

THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE WITH CHANGES IN pH OF LIMESTONE MODIFIED FLYASH PID (St. Clair, Mich.), THE COAL ASH CONSTITUENTS OF PID AND THE LIME CONSTITUENTS OF PID IN LIQUORS CONTAINING THE SOLUBLE CONSTITUENTS OF PID



The modifiers tested were those found to be effective in flotation separation of other minerals and were generally di- or trivalent compounds because the effectiveness of a modifier usually increases with increased valence and decreased ionic radius due to increased adsorptive capacity of the smaller ions by the mineral. The general method of testing each modified flyash and the effect of each modifier consisted of making a concentrated 33 percent modified flyash-water slurry, adding the modifier as required, removing the solid portion of the slurry by centrifuging and adding back to the supernatant liquid a small amount of the solid material. The supernatant liquid containing a small amount of solid material was then placed in a special electrophoresis cell and a voltage applied to cause the particles to move toward an electrode of opposite charge. The speed that the particles traveled to an electrode was proportional to the magnitude of the surface charge and the ZP was calculated from the rate of movement.

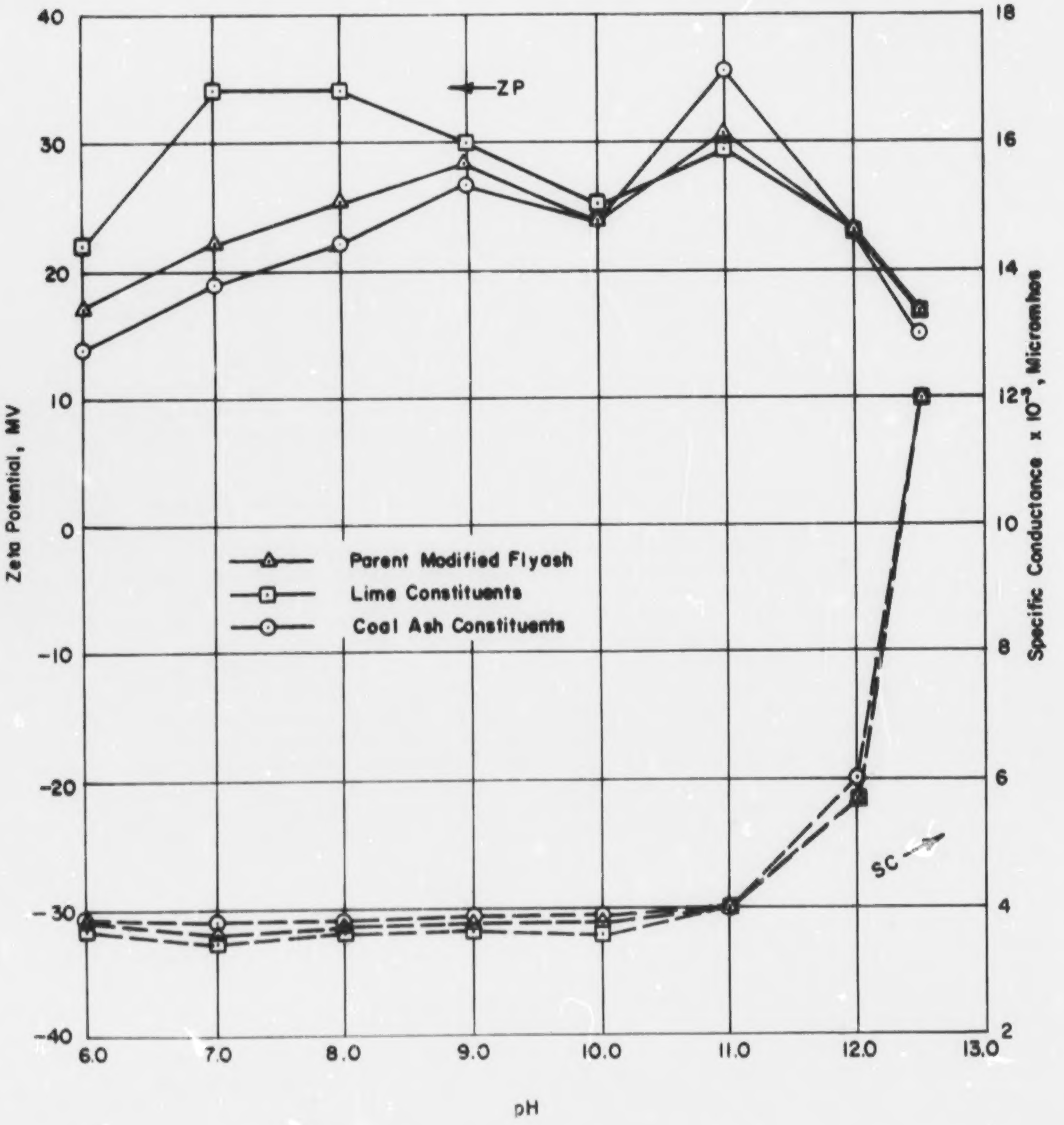
Typical data obtained in the modifier study are given in Figure 5. It was found that FAS was the most effective modifier at the level of addition of 1.0 PPT to a 16.6 percent slurry of PID modified flyash. A 13 millivolt (mv) displacement between the coal ash constituent and parent modified flyash was obtained at pH 10. The ZP of the lime constituent could not be determined due to a lack of sample. However, based on previous ZP tests in which it was determined that the parent modified flyash curve was a resultant of the lime and coal ash constituent, it was indicated that the ZP of the lime constituent was approximately 57 mv resulting in a favorable displacement of 26 mv between the line and parent modified flyash curves. Agglomerate flotation Test 85 was used to test these ZP findings. As noted in Section 3, an improvement in lime grade was achieved.

A preliminary investigation was also made on the ZP of calcium sulfate in order to determine what alteration of surface chemistry might be necessary to effectively separate this constituent of limestone modified flyash, especially from wet collected materials. Initial tests involved ZP measurements on 33 percent slurries of calcium sulfate in distilled water at its natural pH of 6.8 and after lowering the pH to 6.0 by carbonation. The ZP values at both levels of pH was found to be -9 mv. In subsequent tests, the ZP was determined on a slurry of lime and flyash which was sulfated in a stirred reactor with sulfur dioxide to pH 2. The ZP was found to be +14 mv and was attributed to a surface absorption of positive charges during pH adjustment. Further work with high calcium sulfate wet collected samples obtained from Kansas Power and Light and Union Electric showed that modifiers had much less effect than on the dry collected modified flyash. This would be due to either cementing of the samples or to changes in the physical composition of the wet collected flyash as compared to dry collected flyash caused by increased sulfate content.

The ZP studies were beneficial in revealing the nature of the surface charges present and the effects of modifiers used for their control. Improvements in grade were obtained when the ZP data was applied in flotation separations; however, ZP control alone was not found to be sufficient in achieving both high lime yield and recovery. ZP studies of calcium sulfate and wet collected modified flyash showed that additional work would be required to determine the true ZP and what modifiers should be used for ZP control. This may be due to difficulties of sample cementation and the different surface characteristics of

FIGURE 5

THE EFFECT OF THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 4.0 POUNDS PER TON OF TRIVALENT IRON AS FERRIC CHLORIDE TO A 16.5 PERCENT SLURRY CONCENTRATION



calcium sulfate.

## 4.2 Carbonation Studies

Control of the pH of different 33 percent modified flyash flotation slurries was investigated as a means to determine the mechanism of carbonation. Preliminary tests were conducted using a magnetically stirred reactor, a carbon dioxide injection tube, a pH meter interfaced with a recorder and a constant supply of carbon dioxide. The apparatus was designed to continuously monitor and record the change in pH with time. The carbonation step, in which the pH was made as low as possible, and a decarbonation step, in which the pH increased after the supply of carbon dioxide was shut off, were recorded. The results of these tests are shown in Appendix C. The following four observations were noted:

1. Hydrogen sulfide was given off from $D_1D_2$ and $D_1D_3$ limestone modified flyash during carbonation. The odor and coloration of a lead acetate paper was very distinct at pH 9.0 to 9.5 with $D_1D_2$ and to a lesser degree at pH 9.2 with $D_1D_3$. These limestone modified flyashes were produced by TVA by admixing the limestone with the coal prior to combustion. This gas evolution could be an indication that with these modified flyashes the sulfur dioxide was not fixed as calcium sulfate but as some less stable compound, possibly sulfides, as a result of the presence of the coal ash constituents, such as silica, interacting with the lime at the high temperatures present in the boiler.

2. The limestone modified flyashes can be carbonated to pH 6.5 or less while the pH of the dolomite modified flyashes can only be lowered to about 7.5 by carbonation.

3. Carbonation of limestone modified flyashes proceeds rapidly once the soluble lime is converted to calcium carbonate. The dolomite modified flyashes, however, increase in alkalinity once carbonation has lowered the pH to about nine. This increase is shown by the single and double humps in Figures 6 and 7.

4. The increase in pH after carbonation is slow and proceeds in distinct steps. These observations primarily indicate that modified flyash-water slurries can be carbonated and held at pH values around seven for a sufficient length of time to effect flotation separations.

Later tests using modified flyash $D_1D_2$, CI and CM in both 33 and 16.6 percent slurry concentrations showed that the carbon dioxide absorption rate was generally proportional to the rate of change in pH.

In these tests, the resultant pH and the carbon dioxide absorption was plotted against time. The lower slurry concentration was chosen in order to prevent cementitious setting of the modified flyash in the reactor during carbonation. It was indicated that in the initial stages of the reaction, when the absorption rate increases rapidly, soluble lime is being precipitated

FIGURE 6

THE EFFECT OF CARBONATION ON THE pH OF 33 PERCENT SLURRIES OF DOLOMITE MODIFIED FLYASH CI
(St. Louis, Mo.)

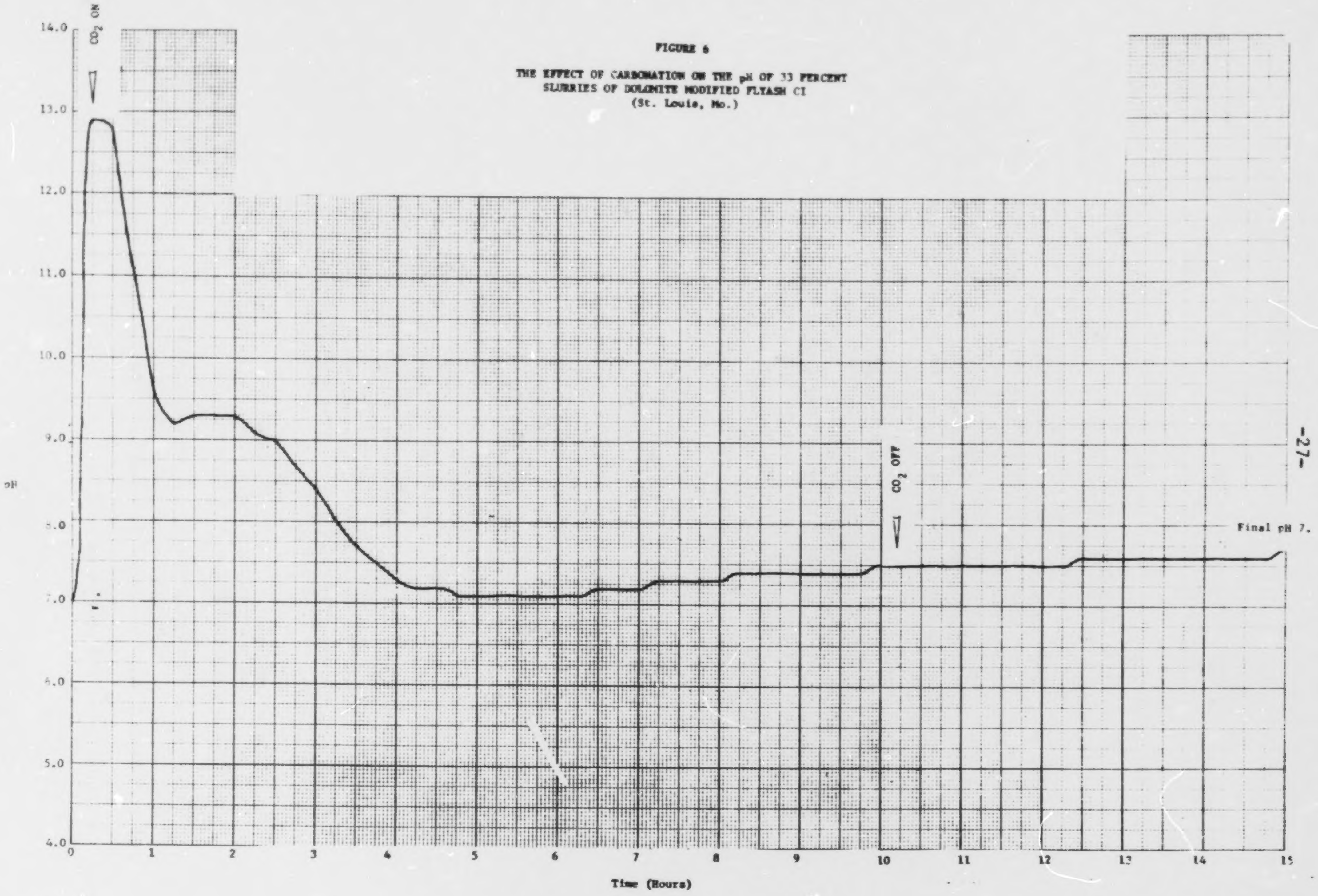
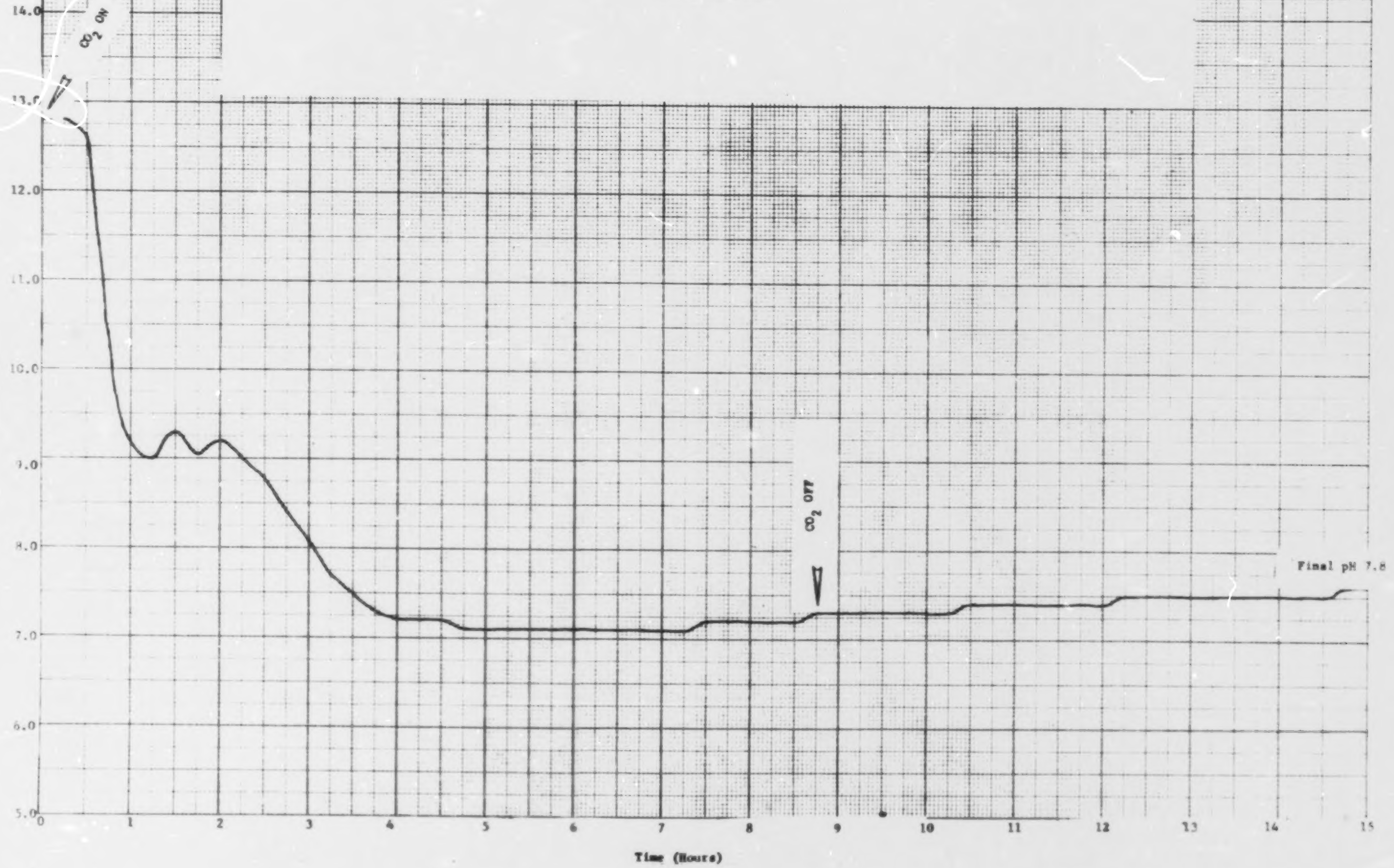


FIGURE 7

THE EFFECT OF CARBONATION ON THE pH OF 33 PERCENT SLURRIES OF DOLOMITE MODIFIED FLYASH CM
(St. Louis, Mo.)



and the pH change is slow. At about pH 12.3 most of the soluble lime has been removed and a sharp decrease in pH and carbon dioxide absorption occurs as the slurry water is titrated. This was seen when comparing the 16.6 percent and 33.0 percent slurry concentration of dolomite modified flyash CM. The increased amounts of soluble lime resulting from the higher slurry concentration required more time and greater amounts of carbon dioxide for precipitation. After the soluble lime is precipitated, there is a sharp decrease in both pH and carbon dioxide absorption as the solution is titrated. Once the equivalence point is passed only small amounts of carbon dioxide are required to complete the titration and precipitate any additional lime brought into solution by equilibrium dynamics. The tests also indicated that initially carbon dioxide is converted to carbonic acid prior to precipitation of soluble lime as evidenced by the initial pH reduction and subsequent rise as lime reacts with carbonic acid. Material balance calculations based on these carbonation tests are shown in Table 4. These calculations indicate that with the exception of the 33 percent CM slurry none of the samples were completely carbonated. The 33 percent CM test resulted in a high value that could not be explained on the basis of calcium carbonate formation and may point to the formation of some magnesium carbonate.

### 4.3 Thermogravimetric Analysis

Thermogravimetric analysis (TGA) of agglomerate flotation fractions of limestone modified flyash showed that the lime particles were about 2/3 carbonated during pH adjustment for flotation separation. The TGA data, shown in Appendix D, also indicated that both the lime particles reporting in the concentrates and those remaining in the unlevitated tails were carbonated to this degree. It was also indicated from the TGA studies that carbonation of the agglomerate flotation slurries served only to control the pH and was not a factor in determining whether a lime particle floated or remained in the tail. The study also showed that there was generally unused emulsion remaining after the agglomerate separation.

The TGA studies were undertaken because during the chemical analysis it was necessary to remove the emulsion before the samples could be accurately weighed. The temperatures required for removal of the oily emulsions approached the calcination temperature of calcium carbonate so that the entire material had to be calcined in order to perform accurate chemical analysis. Since both the emulsion and the carbon dioxide were removed by this drying technique, no statement of the amount of either constituent in a particular flotation fraction could be obtained. It was of interest to correlate the degree of carbonation with the recovery of the calcium fraction from the flotation separation to determine if increased carbon dioxide content yielded a higher lime concentrate and also to observe the effect of increased emulsion addition on the amount of the calcium material floated since preliminary correlations of loss on ignition (LOI) and lime grade indicated that the best recoveries of lime were on fractions having the higher LOI. (8)

Dried TGA samples were weighed on a Cahn Model RG Electrobalance. An XY recorder was calibrated to record both the weight loss as registered by the

## TABLE 4

## CARBONATION TEST

| Sample | Slurry Concentration Percent | Feed Weight Gms. | Grams CaO In Feed | Equivalent Grams of $CaCO_3$ | Equivalent Grams of $CO_2$ | Percent Weight Gain | Percent Carbonated |
|---|---|---|---|---|---|---|---|
| PID | 16.6 | 50 | 14.90 | 26.60 | 11.80 | 2.00 | 17.09 |
| CM | 16.6 | 50 | 9.59 | 17.12 | 7.54 | 3.00 | 39.78 |
| CI | 16.6 | 50 | 8.96 | 16.00 | 7.04 | 4.00 | 56.81 |
| CM | 33.0 | 100 | 19.18 | 32.25 | 15.07 | 17.30 | 114.79 |

electrobalance and the temperature increase as measured by a chromel alumel thermocouple. The fusion furnace used for heating the samples was rated for a maximum of 1200°C.

Agglomerate flotation test fractions chosen for TGA analysis were from those flotation tests showing distinct differences, either favorable or unfavorable, as compared to average test results. The agglomerate flotation tests chosen and the reason for their choice are shown in Table 5.

TABLE 5

AGGLOMERATE FLOTATION TESTS ANALYZED BY TGA

| Test Number | Emulsion Addition Rates, PPT | Reason For Choosing Test |
|---|---|---|
| 111 | 20 | Good grades - low emulsion |
| 121 | 20 | Recarbonation to maintain pH at 7 or below<br>Extensive recleaning |
| 96 | 60 | Good grade and recovery in relation to other factorial tests |
| 95 | 60 | Bad grade and recovery in relation to other factorial tests |
| 73 | 112.6 | Good grades - tested by NAPCA for reactivity |
| 84 | 112.6 | Good grades - high emulsion |
| 82 | 112.6 | Bad grades - fair recovery - high emulsion |
| 85 | 140.7 | High grades - high emulsion - extensive recleaning |
| 115 | 20 | 81.45 percent lime grade - low recovery |
| 124 | | Froth flotation |

Several pure calcium compounds and a modified flyash were determined as a means of correlating the results obtained on TGA fractions.

The degree of carbonation for the flotation samples, as measured by both TGA and LOI methods, shows that the highest flotation grades of lime were generally obtained on the highest carbonated fractions. (8) However, when the amount of lime in any fraction is considered as the sole carbon dioxide absorber during carbonation, it is seen that all particles absorb about the same amount of carbon dioxide. For example, calculation of the degree of carbonation for the $CC_3$ and RT of Test 84 shows that both are carbonated to the same degree or about 29.00 percent. The TGA data on Tests 95 and 196 were of special interest because Test 95 showed rapid increases in pH during separation and resulted in poor grades and recoveries while Test 96 showed good grades and recoveries with stable pH in relation to the other data obtained in the factorial tests. Calculation of the percent carbonation for this test showed that the lime particles of Test 95 were carbonated to a slightly higher degree than those of Test 96.

Since there appears to be essentially no difference in the degree of carbonation between fractions within a single test and between tests, it would appear that carbonation serves only to control pH, through precipitation of soluble lime, and does not affect grade or recovery.

The TGA tests on the tail fractions also showed that unlevitated emulsion remained after completion of the flotation separation. This was indicated by weight loses below 400°C and was especially evident with the higher emulsion addition rates.

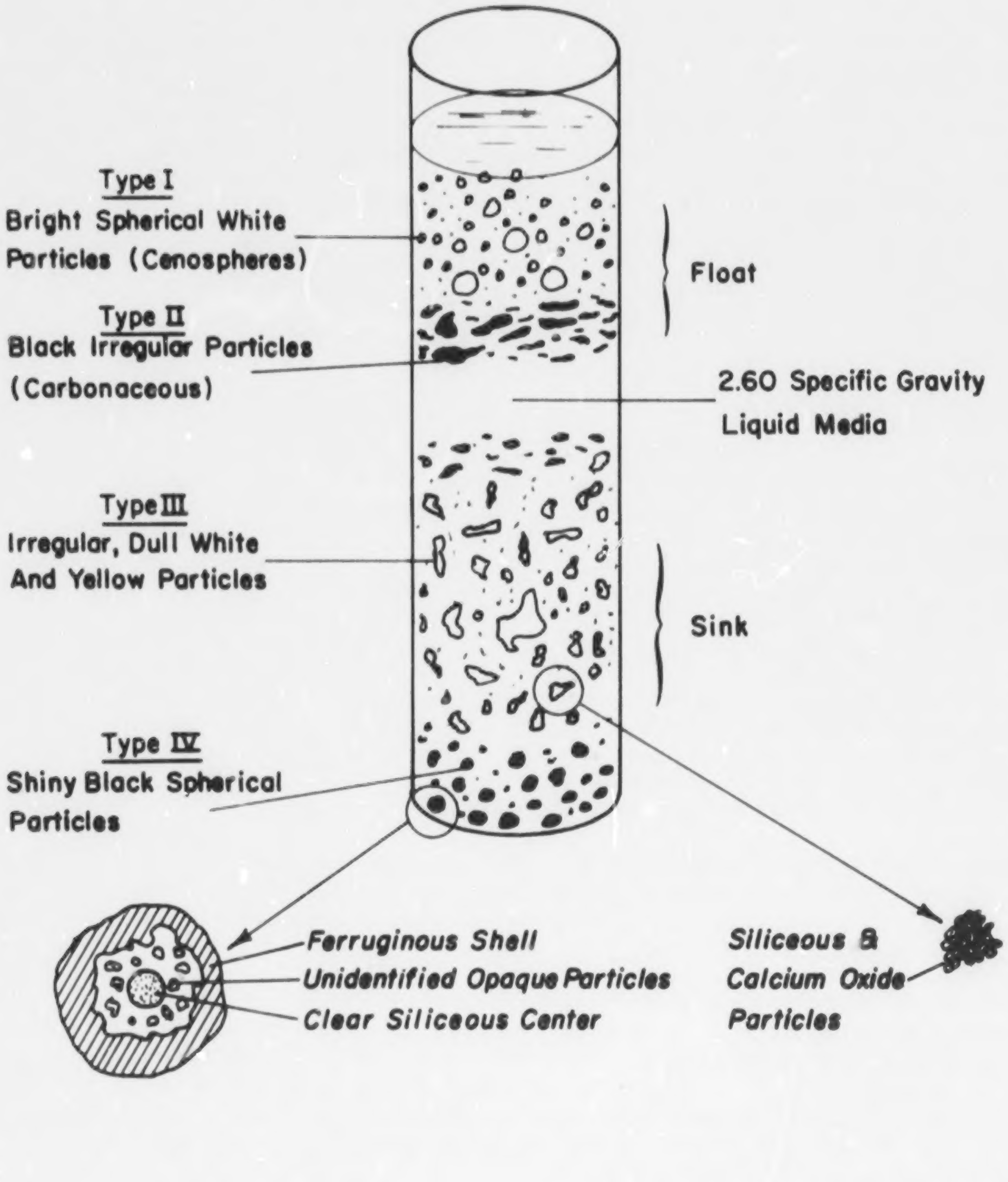
### 4.4 Microscopic Analysis

As a result of the low yields and recoveries of lime obtained and the failure of the corollary tests to suitably explain these low values, additional characterization tests were undertaken. Microscopic examination of fractions of dry collected limestone modified flyash obtained by centrifugation in liquids ranging in specific gravity from 1.0 to 2.6 indicated that this material consisted of four distinct particle types. An example of such a separation is shown in Figure 8. The lightest fraction consisted of bright, white, hollow siliceous cenospheres (Type I). The second float fraction Type II, was black irregular shaped carbonaceous particles having much the same appearance as coked coal particles. Type III, the first sink fraction, consisted of irregular, dull white or yellow particles which were very high in lime. The heaviest fraction, Type IV, was comprised of shiny black spherical particles which were high in iron.

The Type I siliceous cenospheres were found by chemical analysis to consist of the coal ash constituents of limestone modified flyash. These cenospheres were comprised of about 50 percent silica, 25 percent alumina and only about 5 percent lime whereas the Type III irregular dull white or yellow particles consisted of about 50 percent lime. Type III particles, when hand crushed, were of low strength and crumbled into smaller uniform particles, some of which resembled pure calcium carbonate after calcination while others were glassy like silica. Both the Type I and Type IV spherical particles, when crushed, were found to be hollow. The thinner walled Type I siliceous particles were a uniform white color. However, the high iron Type IV particles had thicker walls encircling light colored solid spherical particles that appeared to be siliceous.

Figure 8

# THE 2.60 SPECIFIC GRAVITY SEPARATION OF HEAD PID


Type I
Bright Spherical White Particles (Cenospheres)
Type II
Black Irregular Particles (Carbonaceous)
Type III
Irregular, Dull White And Yellow Particles
Type IV
Shiny Black Spherical Particles
Float
2.60 Specific Gravity Liquid Media
Sink
Ferruginous Shell
Unidentified Opaque Particles
Clear Siliceous Center
Siliceous & Calcium Oxide Particles

These tests indicated that dry collected limestone modified flyash consists of three coal ash fractions that are unaffected by the injection of limestone or dolomite, ie, that are similar to unmodified flyash. The Type III lime fraction is predominately derived from the limestone or dolomite but appears to contain some of the smaller siliceous coal ash particles.

The low bond strength between the siliceous and lime materials in the Type III particles partially accounts for the presence of non-lime material in the lime concentrates and the recovery of relatively pure fractions of lime by softening and abrasion.

## Section 5

## SULFUR RECOVERY

Interest has been expressed in the possibility of recovering sulfur by heating the different modified flyashes in an oxidizing atmosphere. Preliminary sulfur balance tests were conducted on the raw modified flyash samples. These were done using a modified oxidizing combustion furnace-titration technique. Modified flyash PID having a sulfur concentration of 1.80 percent as determined by the Eschka method contained 1.72 percent sulfur by the combustion method. This represents better than a 95 percent recovery of the sulfur from the sample. This recovery can then be compared with the sulfur content contained in a sample of dihydrated calcium sulfate which gave a 91 percent recovery and indicates that the decomposition approaches quantitative yields. In another test using the tailing product from flotation Test 79 which contained 62.5 percent of the original modified ash ($D_1D_2$), the percent sulfur was found to be 1.30. Since sulfur values have not been determined on all of the flotation fractions tested to date, a comparison of this result with the Eschka method for the tailing fraction of flotation Test 79 cannot be made. However, based on the data available, it would appear that about half of the sulfur value occurs in the concentrate and half in the tails. Although these preliminary figures indicate no substantial upgrading of the sulfur value in either fraction, it should be pointed out that:

1. The sulfur dioxide present in either fraction can be removed almost quantitatively by melting modified flyash.

2. The form of the sulfur in the modified ash after flotation has not yet been determined and the decomposition effect may differ from one ash to another.

3. In Test 79, $D_1D_2$ modified ash was used which liberates hydrogen sulfide during carbonation and the resultant sulfur values in the flotation fractions may be lower due to sulfide evolution during carbonation.

Further work will be undertaken on Contract CPA 70-66 to compare the ability of different modified flyashes to liberate hydrogen sulfide during carbonation and evolve sulfur dioxide when heated in an oxidizing atmosphere.

# Section 6

## AGGLOMERATE SIEVING

Tests were undertaken to determine the feasibility of lime recovery from limestone modified flyash by agglomerating the lime fraction in oil-water emulsions in the same manner as agglomerate flotation and then sieving out the unagglomerated coal ash fraction rather than by levitation by air lifting. The results are given in Appendix E. As indicated by the ratios of enrichment shown in the data of Appendix E, little progress was made toward lime concentration. Numerous conditions were tested with little success and it would appear that such a method would not be applicable.

## Section 7

## CONCLUSIONS

The results of extensive bench scale agglomerate flotation studies for recovery of unreacted lime from dry collected limestone modified flyash indicate that continued study in this area is not feasible. Acceptably high grades and yields of lime were not consistently achieved and further substantial bench scale study would have to be undertaken to obtain the required grades and yields for lime recovery to be effected commercially.

The data accumulated indicates that lime recovery from limestone modified flyash may be effected to some degree by pH control and soluble lime precipitation through carbonation, zeta potential control through modifier addition, employment of agglomerate flotation and by recleaning the initial (rougher) concentrates. It was found that relatively pure fractions of lime may be obtained through extended preconditioning. This softens the lime particles in water and the abrasion of the softened particles results in particles of relatively pure lime. Attritional scrubbing tests may be a way of breaking down the lime-siliceous flyash particles; however, no favorable quantitative data were obtained.

Both the physical and chemical characteristics of the constituents of limestone modified flyash and the flotation separation were studied as a means of improving lime grade and yield. It was found that agglomerate flotation was superior to the previously employed froth flotation because of the fineness of the modified flyash.

It was also found that carbonation was necessary to control the pH of the flotation slurry and to reduce the amount of water soluble lime. Carbonation tests showed that, while the carbonation mechanism was different for limestone and dolomite modified flyash, there was sufficient time after carbonation to permit a flotation separation before the pH rose to unacceptably high levels. This pH rise was found to result from solution of lime by equilibrium dynamics.

Zeta potential studies of the surface chemistry of the constituents of limestone modified flyash showed that chemical modifiers were necessary, in addition to pH control, to maintain a favorable displacement between the coal ash and lime fractions. The most effective modifier was di-valent ferrous ammonium sulfate (FAS). However, it was indicated that different modified flyashes might require other modifiers and that zeta potential studies should be undertaken before extensive flotation tests are planned.

Thermogravimetric analysis (TGA) showed that even with the lower emulsion addition rates obtained as a result of the factorial design tests, there was unused emulsion remaining in the unlevitated tail products. The TGA tests also showed that carbonation served only to control pH and did not affect lime grade or recovery.

Microscopic studies indicated that modified flyash was made up of four distinct fractions. The Type III spheres consisted of agglomerated lime-flyash particles which would appear to preclude effective separation by flotation or any other available commercially feasible mineral dressing technique.

Agglomerate sieving was tested and found to be unsatisfactory within the limits of the tests undertaken.

As a result of this investigation, it is concluded that the primary phase of the ECMC process, flotation recovery of lime does not warrant further intensive research. The secondary phase of the ECMC process, mineral wool production in conjunction with sulfur recovery still appears to be feasible. Further work is planned in these areas on Contract CPA 70-66.

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# APPENDIX A

# FLOTATION TEST DATA

MODIFIED FLYASH FLOTATION DATA FOR ASH PID 1A

| TEST NO. | SLURRY PCT. | PITCH RPM | CARB. TIME MIN. | PH VALUES INI. | PH VALUES FIN. | PROMOTOR TYPE | PROMOTOR RATE LB/HR | FROTHER TYPE | FROTHER RATE LB/HR | MODIFIER TYPE | MODIFIER RATE LB/HR | COND. TIME. MIN. | FLOAT TIME. MIN. | PCT. FLOAT | LIME CONCENTRATIONS GRADE PCT. FLOAT | GRADE PCT. TAILS | RECOVERY PCT. FLOAT | RECOVERY PCT. TAILS | RATIO OF ENRICHMENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 33.33 | 1250. | 0.0 | 10.0 | 10.0 | O.ACID | 0.15 | FU.OIL | 0.83 | NONE | 0.00 | 60.0 | 60.00 | 21.73 | 25.40 | 34.90 | 16.44 | 76.36 | 0.76 |
| 2 | 33.33 | 1450. | 0.0 | 10.0 | 10.0 | A25 | 0.49 | F65 | 0.60 | NONE | 0.00 | 120.0 | 75.00 | 42.42 | 27.83 | 30.57 | 35.16 | 43.16 | 0.83 |
| 3 | 33.33 | 1500. | 0.0 | 10.0 | 10.0 | DUO.T | 0.02 | F65 | 0.18 | 40NASI | 0.63 | 10.0 | 30.00 | 26.30 | 27.32 | 27.98 | 21.40 | 44.48 | 0.81 |
| 4 | 33.33 | 1500. | 0.0 | 10.0 | 10.0 | DUO.T | 0.00 | F65 | 0.18 | 40NASI | 0.51 | 3.0 | 30.00 | 7.14 | 23.51 | 29.18 | 5.00 | 84.17 | 0.70 |
| 5 | 33.33 | 1450. | 0.0 | 10.0 | 10.0 | A25 | 0.57 | F65 | 0.48 | 40NASI | 0.41 | 60.0 | 60.00 | 43.94 | 29.33 | 26.99 | 38.38 | 45.54 | 0.87 |
| 6 | 33.33 | 1450. | 0.0 | 10.0 | 10.0 | A25 | 0.71 | F65 | 0.48 | EDTA | 0.22 | 60.0 | 60.00 | 55.94 | 24.68 | 24.75 | 41.12 | 32.12 | 0.73 |
| 7 | 33.33 | 1450. | 0.0 | 10.0 | 10.0 | LAA | 0.02 | F65 | 0.60 | EDTA | 0.22 | 15.0 | 60.00 | 28.09 | 25.64 | 31.00 | 21.45 | 64.61 | 0.76 |
| 8 | 33.33 | 1450. | 0.0 | 10.0 | 10.0 | O.ACID | 0.75 | F65 | 1.20 | 10NASI | 0.02 | 20.0 | 120.00 | 42.11 | 29.46 | 28.21 | 36.95 | 50.22 | 0.88 |
| 9 | 21.73 | 1500. | 0.0 | 10.0 | 10.0 | A25 | 0.35 | F65 | 0.30 | NONE | 0.00 | 10.0 | 42.00 | 55.58 | 31.06 | 26.25 | 51.41 | 34.63 | 0.92 |
| 9A | 16.52 | 1500. | 0.0 | 10.0 | 10.0 | A25 | 0.37 | F65 | 0.31 | NONE | 0.00 | 6.0 | 25.00 | 94.56 | 26.44 | 26.82 | 74.45 | 4.35 | 0.79 |
| 10 | 21.73 | 1500. | 0.0 | 10.0 | 10.0 | A25 | 0.35 | F65 | 0.30 | 0.5 HF | 0.02 | 3.0 | 15.00 | 50.82 | 27.67 | 29.48 | 41.86 | 44.53 | 0.82 |
| 11 | 21.73 | 2200. | 0.0 | 10.0 | 10.0 | A25 | 0.35 | F65 | 0.12 | 0.5 HF | 0.02 | 3.0 | 7.00 | 44.14 | 28.64 | 28.32 | 37.65 | 47.64 | 0.85 |
| 11A | 12.16 | 1500. | 0.0 | 10.0 | 10.0 | 10A303 | 0.21 | F65 | 0.21 | NONE | 0.00 | 4.0 | 8.00 | 10.63 | 28.98 | 28.25 | 9.17 | 75.19 | 0.86 |
| 12 | 21.73 | 2200. | 0.0 | 10.0 | 10.0 | LAA | 0.04 | F65 | 0.12 | 0.5HF | 0.02 | 2.0 | 7.00 | 40.36 | 25.60 | 29.10 | 30.77 | 51.60 | 0.76 |
| 12A | 12.73 | 1500. | 0.0 | 10.0 | 10.0 | 10A303 | 0.20 | F65 | 0.20 | NONE | 0.00 | 4.0 | 8.00 | 20.16 | 27.59 | 29.75 | 16.56 | 70.73 | 0.82 |
| 13 | 21.73 | 2200. | 0.0 | 10.0 | 10.0 | A25 | 0.35 | D250 | 0.14 | 0.5HF | 0.02 | 2.5 | 8.00 | 50.78 | 26.60 | 29.40 | 40.23 | 44.55 | 0.79 |
| 13A | 11.06 | 2200. | 0.0 | 10.0 | 10.0 | 10A303 | 0.12 | D250 | 0.05 | NONE | 0.00 | 2.0 | 5.00 | 9.69 | 26.14 | 29.72 | 7.55 | 79.93 | 0.78 |
| 14 | 21.73 | 2200. | 0.0 | 10.0 | 10.0 | A25 | 0.35 | F65 | 0.12 | SDE610 | 0.02 | 4.0 | 8.00 | 49.35 | 27.90 | 29.30 | 41.00 | 45.28 | 0.83 |
| 14A | 11.07 | 2200. | 0.0 | 10.0 | 10.0 | 10A303 | 0.12 | F65 | 0.24 | NONE | 0.00 | 2.0 | 8.00 | 13.54 | 27.11 | 29.60 | 10.93 | 78.09 | 0.81 |
| 15 | 21.73 | 2200. | 0.0 | 10.0 | 10.0 | A25 | 0.35 | F65 | 0.18 | STANAC | 0.02 | 4.0 | 9.00 | 58.04 | 26.04 | 23.82 | 45.01 | 30.60 | 0.78 |
| 15A | 9.56 | 1500. | 0.0 | 10.0 | 10.0 | 10A303 | 0.14 | F65 | 0.28 | NONE | 0.00 | 2.0 | 9.00 | 11.13 | 22.86 | 23.95 | 7.58 | 63.38 | 0.68 |

MODIFIED FLYASH FLOTATION DATA FOR ASH 2X3PID

| TEST NO. | SLURRY PCT. | PITCH RPM | CARB. TIME MIN. | PH VALUES INI. | PH VALUES FIN. | PROMOTOR TYPE | PROMOTOR RATE LB/HR | FROTHER TYPE | FROTHER RATE LB/HR | MODIFIER TYPE | MODIFIER RATE LB/HR | COND. TIME. MIN. | FLOAT TIME. MIN. | PCT. FLOAT | LIME CONCENTRATIONS GRADE PCT. FLOAT | GRADE PCT. TAILS | RECOVERY PCT. FLOAT | RECOVERY PCT. TAILS | RATIO OF ENRICHMENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 2.57 | 2450. | 0.0 | 10.0 | 10.0 | A25 | 0.54 | A65 | 0.50 | NONE | 0.00 | 5.0 | 3.00 | 10.50 | 24.05 | 26.04 | 6.86 | 62.62 | 0.65 |

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## MODIFIED FLYASH FLOTATION DATA FOR ASH PID

| TEST NO. | SLURRY PCT. | FLTCH RPM | CARB. TIME MIN. | PH VALUES INI. | PH VALUES FIN. | PROMOTOR TYPE | PROMOTOR RATE LB/HR | FROTHER TYPE | FROTHER RATE LB/HR | MODIFIER TYPE | MODIFIER RATE LB/HR | COND. TIME. MIN. | FLOAT TIME. MIN. | PCT. FLOAT | LIME CONCENTRATIONS GRADE PCT. FLOAT | GRADE PCT. TAILS | RECOVERY PCT. FLOAT | RECOVERY PCT. TAILS | RATIO OF ENRICH-MENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 35.71 | 2200. | 0.0 | 12.0 | 12.0 | OLACID | 0.21 | D250 | 0.14 | NONE | 0.00 | 3.0 | 11.00 | 50.26 | 27.90 | 32.65 | 47.07 | 52.28 | 0.94 |
| 21 | 33.33 | 1500. | 40.0 | 12.0 | 6.6 | OLACID | 1.17 | D250 | 0.19 | 40NASI | 0.38 | 5.0 | 11.00 | 32.94 | 26.79 | 24.99 | 29.63 | 67.34 | 0.90 |
| 22 | 45.45 | 1500. | 0.0 | 12.0 | 12.0 | OLACID | 0.70 | D250 | 0.14 | 40NASI | 0.23 | 2.0 | 7.00 | 29.60 | 21.40 | 28.80 | 21.26 | 65.48 | 0.72 |
| 23 | 33.33 | 1500. | 90.0 | 12.0 | 6.0 | OLACID | 0.70 | D250 | 0.14 | 40NASI | 0.38 | 2.0 | 6.25 | 51.38 | 22.20 | 18.35 | 38.29 | 41.01 | 0.75 |
| 24 | 33.33 | 1500. | 60.0 | 12.0 | 9.0 | OLACID | 0.70 | D250 | 0.14 | NONE | 0.00 | 4.0 | 5.00 | 45.67 | 33.16 | 19.80 | 50.83 | 45.27 | 1.11 |
| 25 | 5.41 | -0. | 4.0 | 13.0 | 12.0 | OLACID | 12.73 | D250 | 0.10 | NONE | 0.00 | 2.0 | 3.00 | 75.00 | 32.00 | 30.00 | 80.56 | 33.23 | 1.07 |
| 26 | 5.41 | -0. | 4.0 | 13.2 | 8.4 | OLACID | 16.36 | D250 | 0.14 | NONE | 0.00 | 2.0 | 2.00 | 20.00 | 31.00 | 31.50 | 20.81 | 97.28 | 1.04 |
| 27 | 5.41 | -0. | 4.0 | 13.2 | 12.0 | OLACID | 12.73 | D250 | 0.10 | NONE | 0.00 | 2.0 | 3.00 | 50.00 | 34.00 | 30.30 | 57.07 | 61.03 | 1.14 |
| 28 | 5.41 | -0. | 4.0 | 13.2 | 11.0 | OLACID | 4.09 | D250 | 0.05 | 5.NASI | 0.24 | 2.0 | 5.00 | 38.00 | 29.60 | 29.20 | 37.76 | 68.61 | 0.99 |
| 29 | 5.41 | -0. | 0.0 | 12.5 | 12.5 | OLACID | 4.09 | D250 | 0.05 | 5.NASI | 0.24 | 2.0 | 3.00 | 27.00 | 18.20 | 20.70 | 16.50 | 50.03 | 0.61 |
| 31 | 5.41 | -0. | 4.0 | 13.0 | 12.0 | OLACID | 4.09 | D250 | 0.05 | NONE | 0.00 | 2.0 | 3.00 | 33.00 | 12.45 | 20.72 | 13.79 | 63.99 | 0.42 |

## MODIFIED FLYASH FLOTATION DATA FOR ASH 2X3PID

| TEST NO. | SLURRY PCT. | FLTCH RPM | CARB. TIME MIN. | PH VALUES INI. | PH VALUES FIN. | PROMOTOR TYPE | PROMOTOR RATE LB/HR | FROTHER TYPE | FROTHER RATE LB/HR | MODIFIER TYPE | MODIFIER RATE LB/HR | COND. TIME. MIN. | FLOAT TIME. MIN. | PCT. FLOAT | LIME CONCENTRATIONS GRADE PCT. FLOAT | GRADE PCT. TAILS | RECOVERY PCT. FLOAT | RECOVERY PCT. TAILS | RATIO OF ENRICH-MENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 5.41 | -0. | 0.0 | 13.3 | 13.3 | 5.A825 | 0.91 | D250 | 0.05 | NONE | 0.00 | 2.0 | 3.75 | 58.00 | 19.17 | 26.40 | 30.21 | 32.28 | 0.52 |
| 33 | 5.41 | -0. | 4.0 | 13.3 | 8.0 | 5.A825 | 0.91 | D250 | 0.05 | NONE | 0.00 | 2.0 | 3.75 | -0.00 | 40.70 | 31.20 | -0.00 | -0.00 | 1.11 |

## MODIFIED FLYASH FLOTATION DATA FOR ASH PID

| TEST NO. | SLURRY PCT. | FLOTCR RPM | COND. TIME MIN. | PH VALUES INI. | FIN. | PROMOTOR TYPE | RATE LB/HR | FROTHER TYPE | RATE LB/HR | MODIFIER TYPE | RATE LB/HR | COND. TIME. MIN. | FLOAT TIME. MIN. | PCT. FLOAT | LIME CONCENTRATIONS GRADE PCT. FLOAT | GRADE PCT. TAILS | RECOVERY PCT. FLOAT | PCT. TAILS | RATIO OF ENRICH-MENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | 5.41 | -0. | 0.0 | 13.0 | 13.0 | 5.A825 | 0.91 | D250 | 0.05 | NONE | 0.00 | 2.0 | 3.00 | 41.00 | 31.90 | 35.00 | 43.90 | 70.49 | 1.07 |
| 35 | 5.41 | -0. | 0.0 | 13.0 | 13.0 | OLACID | 1.64 | D250 | 0.20 | CAL240 | 0.38 | 2.0 | 3.50 | 38.00 | 35.70 | 36.20 | 45.54 | 75.34 | 1.20 |
| 37 | 5.46 | -0. | 0.0 | 12.9 | 12.9 | A25 | 2.36 | F65 | 1.98 | 5.FECL | 0.23 | 2.0 | 2.00 | 19.80 | 24.60 | 32.60 | 16.35 | 82.35 | 0.83 |
| 38 | 5.91 | -0. | 0.0 | 13.1 | 13.1 | OLACID | 1.49 | D250 | 0.20 | NONE | 0.00 | 2.0 | 2.00 | 19.09 | 32.30 | 28.60 | 20.70 | 72.44 | 1.08 |
| 39 | 5.25 | -0. | 0.0 | 13.0 | 13.0 | OLACID | 1.69 | F65 | 2.07 | NONE | 0.00 | 2.0 | 2.00 | 27.84 | 29.60 | 32.10 | 27.66 | 77.76 | 0.99 |
| 40 | 5.25 | -0. | 0.0 | 13.0 | 13.0 | OLACID | 1.69 | F65 | 2.07 | NONE | 0.00 | 2.0 | 2.00 | 31.96 | 29.60 | 29.90 | 31.75 | 50.70 | 0.99 |
| 41 | 5.61 | -0. | 4.0 | 13.0 | 7.0 | OLACID | 1.57 | F65 | 1.92 | NONE | 0.00 | 2.0 | 2.50 | 14.42 | 33.50 | 29.60 | 16.22 | 104.14 | 1.12 |
| 42 | 4.95 | -0. | 4.0 | 12.8 | 7.0 | OLACID | 1.78 | F65 | 2.18 | NONE | 0.00 | 2.0 | 2.00 | 8.70 | 30.70 | 27.10 | 8.96 | 90.97 | 1.03 |
| 43 | 5.76 | -0. | 4.0 | 13.0 | 7.0 | OLACID | 1.53 | F65 | 1.87 | NONE | 0.00 | 2.0 | 2.15 | 15.89 | 33.50 | 29.40 | 17.87 | 94.08 | 1.12 |
| 44 | 6.91 | -0. | 0.0 | 13.1 | 13.1 | A25 | 1.82 | F65 | 1.54 | NONE | 0.00 | 2.0 | 2.50 | 20.77 | 27.90 | 29.20 | 19.45 | 79.17 | 0.94 |
| 45 | 6.42 | -0. | 0.0 | 13.0 | 13.0 | A25 | 1.97 | F65 | 1.67 | CAL240 | 3.79 | 2.0 | 3.15 | 26.67 | 27.10 | 26.30 | 24.26 | 61.06 | 0.91 |
| 46 | 6.52 | -0. | 4.0 | 12.8 | 9.8 | OLACID | 1.34 | F65 | 1.64 | 5.EDTA | 0.91 | 2.0 | 3.75 | 28.69 | 31.00 | 29.00 | 29.85 | 82.19 | 1.04 |
| 47 | 6.77 | -0. | 205.0 | 12.9 | 6.7 | OLACID | 1.29 | F65 | 1.58 | CAL240 | 0.36 | 2.0 | 3.00 | 24.41 | 31.40 | 30.30 | 25.73 | 88.10 | 1.05 |
| 48 | 5.56 | -0. | 4.0 | 12.9 | 7.0 | 5.OLAA | 0.50 | F65 | 1.95 | NONE | 0.00 | 2.0 | 3.15 | 18.45 | 28.60 | 29.00 | 17.71 | 91.68 | 0.96 |
| 49 | 6.52 | -0. | 4.0 | 13.0 | 7.0 | 5.OLAA | 0.50 | F65 | 1.64 | NONE | 0.00 | 2.0 | 3.50 | 33.61 | 27.10 | 31.60 | 30.57 | 81.73 | 0.91 |
| 50 | 5.86 | -0. | 4.0 | 13.0 | 7.0 | 5.OLAA | 0.50 | F65 | 1.83 | NONE | 0.00 | 2.0 | 3.30 | 41.28 | 27.70 | 30.10 | 38.39 | 74.16 | 0.93 |
| 51 | 5.96 | -0. | 4.0 | 13.0 | 7.0 | 5.OLAA | 0.50 | F65 | 1.80 | NONE | 0.00 | 2.0 | 3.50 | 54.05 | 28.60 | 31.20 | 51.89 | 72.65 | 0.96 |
| 52 | 6.47 | -0. | 4.0 | 13.0 | 9.9 | A25 | 0.50 | F65 | 1.65 | 5.FECL | 0.45 | 2.0 | 4.00 | 24.79 | 31.90 | 26.30 | 26.55 | 79.53 | 1.07 |
| 53 | 6.47 | -0. | 4.0 | 13.0 | 9.9 | A25 | 0.50 | F65 | 1.65 | 5.FECL | 0.45 | 4.0 | 3.00 | 30.58 | 30.70 | 30.10 | 31.51 | 83.50 | 1.03 |
| 54 | 6.47 | -0. | 4.0 | 13.1 | 9.9 | 5.OLAA | 0.50 | F65 | 1.65 | NONE | 0.00 | 2.0 | 3.00 | 29.75 | 32.30 | 28.80 | 32.26 | 79.90 | 1.08 |
| 55 | 6.52 | -0. | 4.0 | 13.1 | 9.9 | 5.OLAA | 0.50 | F65 | 1.64 | NONE | 0.00 | 2.0 | 4.10 | ****** | 29.60 | 27.90 | ****** | 69.09 | 0.99 |
| 56 | 5.91 | -0. | 4.0 | 13.2 | 9.9 | 5.OLAA | 0.50 | F65 | 1.82 | NONE | 0.00 | 2.0 | 4.00 | 36.36 | 28.60 | 26.10 | 34.91 | 65.31 | 0.96 |
| 57 | 5.91 | -0. | 4.0 | 13.2 | 9.9 | 5.OLAA | 0.50 | F65 | 1.82 | NONE | 0.00 | 2.0 | 4.00 | 40.91 | 27.50 | 26.30 | 37.76 | 63.40 | 0.92 |
| 60 | 5.36 | -0. | 4.0 | 13.4 | 9.9 | 5.OLAA | 0.50 | F65 | 2.05 | NONE | 0.00 | 2.0 | 4.00 | 17.35 | 29.90 | 26.70 | 17.41 | 81.40 | 1.00 |
| 61 | 5.35 | -0. | 4.0 | 13.1 | 9.9 | 0.5A25 | 0.50 | F65 | 2.02 | NONE | 0.00 | 2.0 | 4.00 | 21.21 | 33.30 | 27.50 | 23.71 | 78.33 | 1.12 |

### MODIFIED FLYASH FLOTATION DATA FOR ASH PID

| TEST NO. | SLURRY PCT. | ROTOR RPM | CARB. TIME MIN. | PH VALUES INI. | PH VALUES FIN. | PROMOTOR TYPE | PROMOTOR RATE LB/HR | FROTHER TYPE | FROTHER RATE LB/HR | MODIFIER TYPE | MODIFIER RATE LB/HR | COND. TIME, MIN. | FLOAT TIME, MIN. | PCT. FLOAT | LIME CONCENTRATIONS GRADE PCT. FLOAT | GRADE PCT. TAILS | RECOVERY PCT. FLOAT | RECOVERY PCT. TAILS | RATIO OF ENRICHMENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 | 5.41 | -0. | 0.0 | 9.2 | 9.2 | OLACID | 0.50 | F65 | 2.00 | NONE | 0.00 | 2.0 | 5.00 | 41.00 | 33.30 | 30.30 | 42.07 | 48.55 | 1.03 |
| 64 | 5.41 | -0. | 3.0 | 9.2 | 6.5 | OLACID | 0.50 | F65 | 0.50 | NONE | 0.00 | -0.0 | 5.00 | 20.00 | 32.30 | 30.30 | 19.91 | 64.43 | 1.00 |

### MODIFIED FLYASH FLOTATION DATA FOR ASH PID

| TEST NO. | SLURRY PCT. | ROTOR RPM | CARB. TIME MIN. | PH VALUES INI. | PH VALUES FIN. | PROMOTOR TYPE | PROMOTOR RATE LB/HR | FROTHER TYPE | FROTHER RATE LB/HR | MODIFIER TYPE | MODIFIER RATE LB/HR | COND. TIME, MIN. | FLOAT TIME, MIN. | PCT. FLOAT | LIME CONCENTRATIONS GRADE PCT. FLOAT | GRADE PCT. TAILS | RECOVERY PCT. FLOAT | RECOVERY PCT. TAILS | RATIO OF ENRICHMENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | 5.41 | -0. | 4.0 | 13.2 | 9.2 | OLACID | 0.50 | F65 | 0.50 | NONE | 0.00 | 2.0 | 5.00 | 23.00 | 29.90 | 30.70 | 20.48 | 83.20 | 0.89 |
| 67 | 40.00 | -0. | 0.0 | 13.0 | 13.0 | EMULSN | 66.65 | NONE | 0.00 | NONE | 0.00 | 10.0 | 15.00 | 65.25 | 33.07 | 37.00 | 64.26 | 10.53 | 0.98 |
| 69 | 33.33 | 1100. | 55.0 | 13.1 | 6.7 | EMULSN | 112.60 | NONE | 0.00 | 5.FECL | 2.00 | 20.0 | 15.00 | 115.75 | 35.76 | 16.30 | 123.26 | 0.93 | 1.06 |
| 70 | 5.76 | -0. | 3.0 | 13.2 | 9.0 | BCACID | 0.50 | F65 | 0.50 | NONE | 0.00 | 2.0 | 3.00 | 14.95 | 33.90 | 34.20 | 15.10 | 86.62 | 1.01 |

### MODIFIED FLYASH FLOTATION DATA FOR ASH DID3

| TEST NO. | SLURRY PCT. | ROTOR RPM | CARB. TIME MIN. | PH VALUES INI. | PH VALUES FIN. | PROMOTOR TYPE | PROMOTOR RATE LB/HR | FROTHER TYPE | FROTHER RATE LB/HR | MODIFIER TYPE | MODIFIER RATE LB/HR | COND. TIME, MIN. | FLOAT TIME, MIN. | PCT. FLOAT | LIME CONCENTRATIONS GRADE PCT. FLOAT | GRADE PCT. TAILS | RECOVERY PCT. FLOAT | RECOVERY PCT. TAILS | RATIO OF ENRICHMENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 71 | 5.96 | -0. | 0.0 | 13.4 | 7.0 | OLACID | 0.50 | F65 | 0.50 | 5.FECL | 0.50 | 2.0 | 1.30 | 4.50 | 25.60 | 22.50 | 4.62 | 84.46 | 1.03 |

### MODIFIED FLYASH FLOTATION DATA FOR ASH DID2

| TEST NO. | SLURRY PCT. | ROTOR RPM | CARB. TIME MIN. | PH VALUES INI. | PH VALUES FIN. | PROMOTOR TYPE | PROMOTOR RATE LB/HR | FROTHER TYPE | FROTHER RATE LB/HR | MODIFIER TYPE | MODIFIER RATE LB/HR | COND. TIME, MIN. | FLOAT TIME, MIN. | PCT. FLOAT | LIME CONCENTRATIONS GRADE PCT. FLOAT | GRADE PCT. TAILS | RECOVERY PCT. FLOAT | RECOVERY PCT. TAILS | RATIO OF ENRICHMENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RC1 73 | 33.33 | 1100. | 35.0 | 12.9 | 7.0 | EMULSN | 112.60 | NONE | 0.00 | 5.FECL | 2.00 | 20.0 | 5.00 | 17.15 | 30.22 | 20.96 | 22.98 | 77.01 | 1.34 |
| RC2 73 | 29.29 | 1100. | -0.0 | 12.9 | 7.0 |  | -0.00 |  | -0.00 |  | -0.00 | 20.0 | 5.00 | 9.79 | 36.62 | 17.37 | 17.10 | 74.76 | 1.75 |
| RC3 73 | 27.20 | 1100. | -0.0 | 12.9 | 7.0 |  | -0.00 |  | -0.00 |  | -0.00 | 20.0 | 5.00 | 8.59 | 31.60 | 16.03 | 15.64 | 84.35 | 1.82 |
| CC1 73 | 6.42 | 1100. | -0.0 | 7.0 | 7.0 |  | -0.00 |  | -0.00 |  | -0.00 | 1.0 | 5.00 | 24.61 | 49.09 | 24.06 | 39.97 | 60.00 | 1.62 |
| CC2 73 | 3.14 | 1100. | -0.0 | 7.0 | 7.0 |  | -0.00 |  | -0.00 |  | -0.00 | 1.0 | 5.00 | 24.53 | 56.44 | 30.19 | 37.80 | 62.22 | 1.54 |
| CC3 73 | 2.51 | 1100. | -0.0 | 7.0 | 7.0 |  | -0.00 |  | -0.00 |  | -0.00 | 1.0 | 5.00 | 17.49 | 49.88 | 27.74 | 27.61 | 72.43 | 1.58 |

### MODIFIED FLYASH FLOTATION DATA FOR ASH PID

| TEST NO. | SLURRY PCT. | ROTOR RPM | CARB. TIME MIN. | PH VALUES INI. | PH VALUES FIN. | PROMOTOR TYPE | PROMOTOR RATE LB/HR | FROTHER TYPE | FROTHER RATE LB/HR | MODIFIER TYPE | MODIFIER RATE LB/HR | COND. TIME, MIN. | FLOAT TIME, MIN. | PCT. FLOAT | LIME CONCENTRATIONS GRADE PCT. FLOAT | GRADE PCT. TAILS | RECOVERY PCT. FLOAT | RECOVERY PCT. TAILS | RATIO OF ENRICHMENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RC1 76 | 33.33 | 1100. | 25.0 | 10.5 | 6.9 | EMULSN | 112.60 | NONE | 0.00 | 5.FECL | 4.00 | 2.0 | 15.00 | 55.87 | 33.26 | 27.57 | 62.38 | 38.90 | 1.12 |
| CT1 76 | 16.27 | 1100. | -0.0 | 6.9 | 6.9 | | -0.00 | | -0.00 | | -0.00 | -0.0 | 5.00 | 48.70 | 38.51 | 28.27 | 56.39 | 43.60 | 1.16 |
| CT2 76 | 9.82 | 1100. | -0.0 | 6.9 | 6.9 | | -0.00 | | -0.00 | | -0.00 | -0.0 | 5.00 | 44.44 | 40.43 | 36.97 | 46.65 | 53.34 | 1.05 |
| CT3 76 | 4.61 | 1100. | -0.0 | 6.9 | 6.9 | | -0.00 | | -0.00 | | -0.00 | -0.0 | 5.00 | 72.37 | 41.54 | 37.54 | 74.36 | 25.66 | 1.03 |
| CT4 76 | 3.38 | 1100. | -0.0 | 6.9 | 6.9 | | -0.00 | | -0.00 | | -0.00 | -0.0 | 5.00 | 20.35 | 45.89 | 40.43 | 22.49 | 77.52 | 1.10 |
| CT5 76 | 0.71 | 1100. | -0.0 | 6.9 | 6.9 | | -0.00 | | -0.00 | | -0.00 | -0.0 | 5.00 | 19.30 | 50.53 | 44.80 | 21.25 | 78.78 | 1.10 |

### MODIFIED FLYASH FLOTATION DATA FOR ASH PID

| TEST NO. | SLURRY PCT. | ROTOR RPM | CARB. TIME MIN. | PH VALUES INI. | PH VALUES FIN. | PROMOTOR TYPE | PROMOTOR RATE LB/HR | FROTHER TYPE | FROTHER RATE LB/HR | MODIFIER TYPE | MODIFIER RATE LB/HR | COND. TIME, MIN. | FLOAT TIME, MIN. | PCT. FLOAT | LIME CONCENTRATIONS GRADE PCT. FLOAT | GRADE PCT. TAILS | RECOVERY PCT. FLOAT | RECOVERY PCT. TAILS | RATIO OF ENRICHMENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 76 | 33.33 | 1100. | 30.0 | 13.1 | 6.7 | EMULSN | 112.60 | NONE | 0.00 | 5.FECL | 4.00 | 20.0 | 11.00 | 49.50 | 34.71 | 23.54 | 57.68 | 55.31 | 1.17 |

### MODIFIED FLYASH FLOTATION DATA FOR ASH DID2

| TEST NO. | SLURRY PCT. | ROTOR RPM | CARB. TIME MIN. | PH VALUES INI. | PH VALUES FIN. | PROMOTOR TYPE | PROMOTOR RATE LB/HR | FROTHER TYPE | FROTHER RATE LB/HR | MODIFIER TYPE | MODIFIER RATE LB/HR | COND. TIME, MIN. | FLOAT TIME, MIN. | PCT. FLOAT | LIME CONCENTRATIONS GRADE PCT. FLOAT | GRADE PCT. TAILS | RECOVERY PCT. FLOAT | RECOVERY PCT. TAILS | RATIO OF ENRICHMENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RC1 79 | 33.33 | 1100. | 35.0 | 13.0 | 7.0 | EMULSN | 112.60 | NONE | 0.00 | 5.FECL | 2.00 | 20.0 | 5.00 | 10.17 | 47.70 | 22.39 | 21.52 | 89.19 | 2.12 |
| RC2 79 | 30.95 | 1100. | -0.0 | 13.0 | 7.0 | | -0.00 | | -0.00 | | -0.00 | 20.0 | 5.00 | 12.16 | 42.19 | 19.65 | 22.91 | 77.09 | 1.88 |
| RC3 79 | 26.25 | 1100. | -0.0 | 13.0 | 7.0 | | -0.00 | | -0.00 | | -0.00 | 20.0 | 5.00 | 8.36 | 39.55 | 19.78 | 16.82 | 92.25 | 2.01 |
| CC1 79 | 3.51 | 1100. | -0.0 | 7.0 | 7.0 | | -0.00 | | -0.00 | | -0.00 | 1.0 | 5.00 | 20.61 | 58.19 | 45.07 | 25.12 | 74.91 | 1.22 |
| CC2 79 | 4.16 | 1100. | -0.0 | 7.0 | 7.0 | | -0.00 | | -0.00 | | -0.00 | 1.0 | 5.00 | 29.83 | 51.36 | 38.29 | 36.32 | 63.68 | 1.22 |
| CC3 79 | 2.56 | 1100. | -0.0 | 7.0 | 7.0 | | -0.00 | | -0.00 | | -0.00 | 1.0 | 5.00 | 39.80 | 46.38 | 35.00 | 46.67 | 53.08 | 1.17 |

```
                               MODIFIED FLYASH FLOTATION DATA FOR ASH    PID
                                                                                  LIME CONCENTRATIONS
                                                                             GRADE GRADE  RECOVERY    RATIO OF
                                 PROMOTOR       FROTHER      MODIFIER   COND. FLOAT    PCT.  PCT.  PCT.  PCT.   ENRICH-
              CARB.                                                                                       
TEST SLURRY PITCH TIME  PH VALUES  TYPE   RATE    TYPE   RATE    TYPE    RATE  TIME. TIME.  PCT. PCT.  PCT.  PCT.  PCT.   MENT
 NO.  PCT.   RPM  MIN.  INI. FIN.         LB/HR          LB/HR           LB/HR  MIN.  MIN. FLOAT FLOAT TAILS FLOAT TAILS
HCI 60 26.57 1100.   0.0 12.4 13.4 EMULSN 112.60  NONE    0.00 5.FECL    2.00  30.0 13.00 58.01 24.99 30.89 48.66 29.15  0.84
CT1 60 16.62 1100.  -0.0 12.4 13.4        -0.00          -0.00          -0.00   1.0  5.00 66.80 23.92 27.13 63.94 36.05  0.96
CT2 60 13.42 1100.  -0.0 12.4 13.4        -0.00          -0.00          -0.00   1.0  5.00 77.27 23.72 24.68 76.62 23.39  0.99
CT3 60 10.65 1100.  -0.0 12.4 13.4        -0.00          -0.00          -0.00   1.0  5.00 76.63 23.81 23.45 76.93 23.10  1.00
CT4 60  8.41 1100.  -0.0 12.4 13.4        -0.00          -0.00          -0.00   1.0  5.00 74.83 23.76 23.85 74.67 25.32  1.00

                               MODIFIED FLYASH FLOTATION DATA FOR ASH   DID2
                                                                                  LIME CONCENTRATIONS
                                                                             GRADE GRADE  RECOVERY    RATIO OF
                                 PROMOTOR       FROTHER      MODIFIER   COND. FLOAT    PCT.  PCT.  PCT.  PCT.   ENRICH-
              CARB.
TEST SLURRY PITCH TIME  PH VALUES  TYPE   RATE    TYPE   RATE    TYPE    RATE  TIME. TIME.  PCT. PCT.  PCT.  PCT.  PCT.   MENT
 NO.  PCT.   RPM  MIN.  INI. FIN.         LB/HR          LB/HR           LB/HR  MIN.  MIN. FLOAT FLOAT TAILS FLOAT TAILS
E1     80.30 1100.  25.0 10.5  6.9 EMULSN 112.60  NONE    0.00 5.FECL    2.00  20.0 15.00 92.39 25.29 15.14140.76  5.78  1.52

                               MODIFIED FLYASH FLOTATION DATA FOR ASH    PID
                                                                                  LIME CONCENTRATIONS
                                                                             GRADE GRADE  RECOVERY    RATIO OF
                                 PROMOTOR       FROTHER      MODIFIER   COND. FLOAT    PCT.  PCT.  PCT.  PCT.   ENRICH-
              CARB.
TEST SLURRY PITCH TIME  PH VALUES  TYPE   RATE    TYPE   RATE    TYPE    RATE  TIME. TIME.  PCT. PCT.  PCT.  PCT.  PCT.   MENT
 NO.  PCT.   RPM  MIN.  INI. FIN.         LB/HR          LB/HR           LB/HR  MIN.  MIN. FLOAT FLOAT TAILS FLOAT TAILS
E2     33.33 1100.  12.0 12.0  9.5 EMULSN 112.60 NONE     0.00  FE       0.40   5.0 10.00 68.17 28.56 30.98 65.36 19.00  0.96

                               MODIFIED FLYASH FLOTATION DATA FOR ASH    PID
                                                                                  LIME CONCENTRATIONS
                                                                             GRADE GRADE  RECOVERY    RATIO OF
                                 PROMOTOR       FROTHER      MODIFIER   COND. FLOAT    PCT.  PCT.  PCT.  PCT.   ENRICH-
              CARB.
TEST SLURRY PITCH TIME  PH VALUES  TYPE   RATE    TYPE   RATE    TYPE    RATE  TIME. TIME.  PCT. PCT.  PCT.  PCT.  PCT.   MENT
 NO.  PCT.   RPM  MIN.  INI. FIN.         LB/HR          LB/HR           LB/HR  MIN.  MIN. FLOAT FLOAT TAILS FLOAT TAILS
RI  63 23.32 1100.  11.0 12.9  8.0 EMULSN 112.60 NONE     0.00  FE       0.40   5.0 20.00 80.92 31.07 17.59 84.39  6.28  1.04
CT1 63 22.80 1100.  -0.0 12.9  8.0        -0.00          -0.00          -0.00   1.0 10.00 90.20 32.24 20.34 93.60  6.42  1.04
CT2 63 26.74 1100.  -0.0 12.9  8.0        -0.00          -0.00          -0.00   1.0 10.00 96.98 32.70 17.50 98.36  1.64  1.01
CT3 63 26.14 1100.  -0.0 12.9  8.0        -0.00          -0.00          -0.00   1.0 10.00 97.44 33.14 15.63 98.75  1.22  1.01
CC-083 25.04 1100.  -0.0 12.9  8.0        -0.00          -0.00          -0.00   1.0 10.00 31.33 35.88 31.65 33.92 65.69  1.08
```

## TABLE 2A

## AGGLOMERATE FLOTATION TEST NO. 84 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 80 ml 10,000 PPM Fe solution added (4.0 PPT) and mixed for 5 minutes.
2. 400 grams of PID flyash added; slurry (16.5%) condition @ 1100 RPM.
3. Carbonate to pH 7 @ 2400 RPM and then add emulsion at rate of 140.75 lb/ton.
4. Adjust rotor RPM empirically to just maintain suspension.
5. Collect float until froth breaks - 7 minutes.
6. Reclean concentrate.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.00 | 1.03 | 395.88 | 29.79 | | | |
| 690312 | RT | 226.00 | 15.23 | 191.58 | 20.26 | 47.89 | 32.57 | ---- |
| ------ | RC | 297.58 | 23.14 | 228.72 | 35.13 | 57.18 | 67.43 | 1.18 |
| 690308 | $CT_1$ | 116.15 | 18.54 | 94.90 | 26.82 | 23.72 | 21.35 | ---- |
| ------ | $CC_1$ | 181.08 | 26.10 | 133.82 | 41.02 | 33.45 | 46.07 | 1.38 |
| 690309 | $CT_2$ | 69.00 | 21.52 | 54.15 | 32.29 | 13.53 | 14.67 | ---- |
| ------ | $CC_2$ | 112.08 | 28.92 | 79.67 | 46.96 | 19.92 | 31.39 | 1.58 |
| 690311 | $CT_3$ | 36.08 | 22.25 | 28.05 | 34.53 | 7.01 | 8.12 | ---- |
| 690310 | $CC_3$ | 76.00 | 32.08 | 51.62 | 51.27 | 12.90 | 22.21 | 1.72 |

## TABLE 3A

## AGGLOMERATE FLOTATION TEST NO. 85 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 20 ml 10,000 PPM Fe as ferrous ammonium sulfate (1.0 PPT) added and mixed for 3 minutes.

2. 400 grams of PID flyash added; slurry (16.6%), condition @ 1700 RPM for 15 minutes.

3. Carbonate to pH 10.0 @ 2200 RPM and then add emulsion at rate of 140.75 PPT.

4. Adjust rotor speed empirically during float.

5. Collect float in 3-5 minute increments.

6. Reclean float products separately.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| Feed | | 400.00 | 1.03 | 395.98 | 29.79 | | | |
| 690363 | RT | 19.0 | 8.55 | 17.38 | 19.69 | 4.66 | 2.77 | ---- |
| A+B+C | Total RC | 437.9 | 19.35 | 353.20 | 30.26 | 95.31 | 89.71 | 1.02 |
| A | 1-RC | 141.7 | 24.81 | 106.55 | 47.67 | 28.75 | 42.80 | 1.61 |
| 690366 | 1-CT | 36.2 | 16.40 | 30.26 | 30.76 | 8.16 | 7.81 | ---- |
| 1-CC1+1-CC2 | Total CC | 105.5 | 27.69 | 76.29 | 54.66 | 20.59 | 34.99 | |
| 690364 | 1-$CC_1$ | 68.5 | 28.95 | 48.67 | 60.29 | 13.13 | 24.62 | 2.02 |
| 690365 | 1-$CC_2$ (1700) | 37.0 | 25.35 | 27.62 | 44.76 | 7.45 | 10.37 | 1.50 |
| B | 2-RC | 93.3 | 18.59 | 75.96 | 26.44 | 20.49 | 16.85 | 0.89 |
| 690368 | 2-CT | 16.6 | 11.53 | 14.69 | 20.44 | 3.96 | 2.51 | ---- |
| D+690367 | Total CC | 76.7 | 20.12 | 61.27 | 27.89 | 16.53 | 14.34 | 0.94 |
| D | 2-$CC_1$ | 56.0 | 21.52 | 43.95 | 26.50 | 11.85 | 10.51 | 0.96 |
| 690367 | 2-CC (1700) | 20.7 | 16.35 | 17.32 | 26.34 | 4.67 | 3.82 | 0.88 |
| 690369 | 2-$CT_2$ | 15.3 | 15.28 | 12.96 | 23.80 | 3.49 | 2.56 | --- |
| E | 2-$CC_2$ | 40.7 | 23.86 | 30.99 | 30.46 | 8.36 | 7.92 | 1.02 |
| 690370 | 2-$CT_3$ | 13.8 | 13.70 | 11.91 | 26.47 | 3.21 | 2.64 | ---- |
| F | 2-$CC_3$ | 26.9 | 29.08 | 19.08 | 32.96 | 5.14 | 5.27 | 1.11 |
| 690371 | 2-$CT_4$ | 5.5 | 14.57 | 4.70 | 28.44 | 1.[illegible]6 | 1.12 | ---- |
| 690372 | 2-$CC_4$ | 21.4 | 32.79 | 14.38 | 34.39 | 3.86 | 4.15 | 1.15 |
| C | 3-RC | 202.9 | 15.88 | 170.69 | 20.97 | 46.06 | 30.05 | 0.70 |
| 690373 | 3-$CT_1$ | 5.9 | 12.53 | 5.16 | 19.38 | 1.39 | 0.83 | ---- |
| G | 3-$CC_1$ | 197.0 | 15.98 | 165.53 | 21.02 | 44.66 | 29.21 | 0.71 |
| 690374 | 3-$CT_2$ | 4.0 | 11.76 | 3.53 | 18.42 | 0.95 | 0.54 | ---- |
| H | 3-$CC_2$ | 193.0 | 16.07 | 162.00 | 21.08 | 43.71 | 28.66 | 1.00 |
| 690375 | 3-$CT_3$ | 3.8 | 13.10 | 3.00 | 19.21 | 0.69 | 0.53 | ---- |
| 690376 | 3-$CC_3$ | 189.2 | 21.91 | 158.70 | 21.13 | 42.82 | 28.14 | 0.71 |

## TABLE 4A

## EMULSION FLOTATION TEST NO. 86 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 20 ml 10,000 PPM FAS added, stirred for 5 minutes.
2. 400 grams PID added, conditioned at 2400 RPM for 15 minutes, carbonated to pH 10.0
3. 2.0 PPT sodium oleate added, conditioned for two minutes.
4. Floated in 5 minute increments, re-cleaned with additions of sodium oleate and F65 frother.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 27.79 | | | |

TEST ABORTED

NOT SUBMITTED FOR CHEMICAL ANALYSIS

## TABLE 4A

## EMULSION FLOTATION TEST NO. 86 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 20 ml 10,000 PPM FAS added, stirred for 5 minutes.
2. 400 grams PID added, conditioned at 2400 RPM for 15 minutes, carbonated to pH 10.0
3. 2.0 PPT sodium oleate added, conditioned for two minutes.
4. Floated in 5 minute increments, re-cleaned with additions of sodium oleate and F65 frother.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 27.79 | | | |

TEST ABORTED

NOT SUBMITTED FOR CHEMICAL ANALYSIS

## TABLE 6A

## AGGLOMERATE FLOTATION TEST NO. 88 LIMESTONE MODIFIED FLYASH PID

1. 1600 ml $H_2O$ added to flotation cell, 24 ml of 10,000 PPM Al solution added (0.6 PPT) and mixed for 5 min.
2. 800 grams of PID flyash added, slurry (33.0%), condition for 15 min. @ 1700 RPM.
3. Carbonate to pH 8 and add emulsion at rate of 140.75 lb/ton.
4. Adjust rotor RPM empirically to just maintain suspension.
5. Collect float in 3-5 min. increments.
6. Reclean as conditions indicate.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| ------ | FEED | 800.0 | 1.03 | 791.76 | 29.79 | | | |
| 690409 | RT | 169.4 | 16.88 | 140.81 | 25.38 | 17.60 | 15.00 | |
| ------ | RC-I | 320.5 | 20.69 | 254.21 | 30.07 | 31.78 | 32.08 | 1.01 |
| 690410 | CT1-I | 148.4 | 23.26 | 113.88 | 30.80 | 14.24 | 14.72 | |
| ------ | CC1-I | 172.1 | 18.47 | 140.33 | 29.48 | 17.54 | 17.36 | 0.99 |
| 690411 | CT2-I | 71.2 | 20.07 | 56.91 | 30.76 | 7.11 | 7.35 | |
| ------ | CC2-I | 100.9 | 17.33 | 83.42 | 28.61 | 10.43 | 10.01 | 0.96 |
| 690412 | CT3-I | 43.8 | 15.94 | 36.82 | 26.65 | 4.60 | 4.12 | |
| ------ | CC3-I | 57.1 | 18.39 | 46.60 | 30.16 | 5.83 | 5.90 | 1.01 |
| 690413 | CT4-I | 19.3 | 17.11 | 16.00 | 28.83 | 2.00 | 1.94 | |
| 690414 | CC-I | 37.8 | 19.06 | 30.60 | 30.85 | 3.83 | 3.96 | 1.04 |
| ------ | RC-II | 210.1 | 17.95 | 172.39 | 26.19 | 21.55 | 18.94 | 0.88 |
| 690415 | CT1-II | 80.0 | 21.78 | 62.58 | 31.37 | 7.82 | 82.4 | |
| ------ | CC1-II | 130.1 | 15.60 | 109.81 | 23.23 | 13.73 | 10.70 | 0.78 |
| 690416 | CT2-II | 25.7 | 18.68 | 20.90 | 28.00 | 2.61 | 2.46 | |
| ------ | CC2-II | 104.4 | 14.84 | 88.91 | 22.11 | 11.11 | 8.25 | 0.74 |
| 690417 | CT3-II | 11.9 | 15.04 | 10.11 | 22.79 | 1.26 | 0.97 | |
| ------ | CC3-II | 92.5 | 14.82 | 78.80 | 22.32 | 2.45 | 7.28 | 0.74 |
| 690418 | CT4-II | 23.0 | 14.72 | 19.61 | 22.32 | 2.45 | 1.84 | |
| 690419 | CC-II | 69.5 | 14.83 | 59.19 | 21.92 | 7.40 | 5.44 | 0.74 |
| ------ | RC-III | 204.6 | 20.35 | 162.97 | 28.72 | 20.37 | 19.64 | 0.96 |
| 690420 | CT1-III | 85.3 | 19.96 | 68.27 | 28.74 | 8.53 | 8.23 | |
| 690421 | CC-III | 119.3 | 20.62 | 94.70 | 28.70 | 11.84 | 11.40 | 0.96 |

## TABLE 7A

## EMULSION FLOTATION TEST NO. 89 LIMESTONE MODIFIED FLYASH PID

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.70 | | | |

DEMONSTRATION TEST - NOT PERFORMED

## TABLE 8A

## FLOTATION STANDARD CONDITIONS AND VARIABLE FACTORS INCORPORATED IN TESTS 90 THROUGH 107 WHICH ARE ENCOMPASSED BY THE FACTORIAL DESIGN EXPERIMENT TO IMPROVE FLOTATION SEPARATION OF LIME FROM LIMESTONE MODIFIED FLYASH

### Standard Conditions

**Flyash** - Dry-collected limestone modified flyash, Detroit Edison Co., St. Clair, Michigan

**Pulp Density** - 16.67 percent slurry

**Mixing** - Mix flyash and water for 15 minutes at 1700 RPM rotor speed before modifier addition

**Modifier** - 1.0 pound per ton (PPT) ferrous ammonium sulfate

**Carbonation** - Carbonate immediately upon completion of mixing at 2400 RPM rotor speed.

**pH** - Carbonate to pH 10, add emulsion and lower pH to 7 through further carbonation

**Emulsion** - 50 percent water, 25 percent #2 fuel oil, 22 1/2 percent tall oil, 2 1/2 percent sodium alkylarylsulfonate

**Rougher Separation** - four minutes

**Cleaner Separations** - two minutes

**Recleaning** - Reclean tail at 1700 RPM except TC, which is recleaned at 1150 RPM

**Make Up Water** - Use recycle water when possible

### Factors

| | | Low Level | High Level |
|---|---|---|---|
| Emulsion addition rate in PPT = | A | 60 | 100 |
| Conditioning time in minutes after addition of emulsion = | B | 5 | 10 |
| Rotor speed of impeller during separations in RPM = | C | 1150 | 1700 |
| Rosin content of tall oil in percent = | D | 18 | 28 |

## TABLE 8A (Continued)

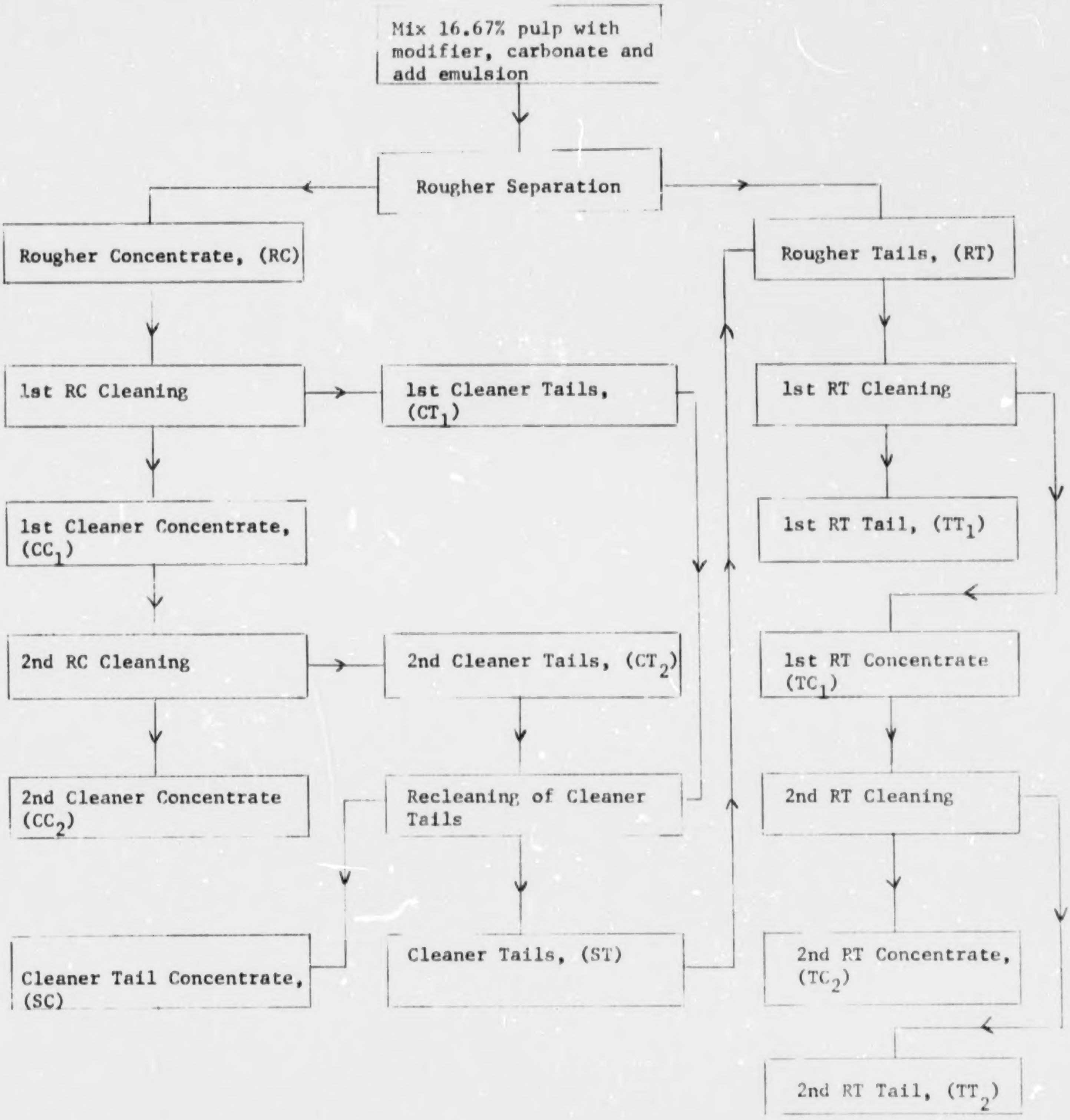
## FACTORIAL DESIGN RESPONSE DATA AND FACTOR LEVELS

|   | -1 | +1 |
|---|---|---|
| A | 60 | 100 |
| B | 5 | 10 |
| C | 1150 | 1700 |
| D | 18 | 28 |

| Flotation Test No. | A | B | C | D | Grade | Yield | Grade x Yield $\times 10^{-2}$ |
|---|---|---|---|---|---|---|---|
| 98 | -1 | -1 | -1 | -1 | 30.30 | 85.13 | 0.2565 |
| 102 | -1 | -1 | -1 | 1 | 33.31 | 69.50 | 0.2315 |
| 107 | -1 | -1 | 1 | -1 | 34.50 | 69.40 | 0.2394 |
| 99 | -1 | -1 | 1 | 1 | 31.63 | 78.06 | 0.2469 |
| 96 | -1 | 1 | -1 | -1 | 33.13 | 86.09 | 0.2852 |
| 95 | -1 | 1 | -1 | 1 | 28.60 | 50.06 | 0.1432 |
| 103 | -1 | 1 | 1 | -1 | 30.46 | 81.68 | 0.2315 |
| 104 | -1 | 1 | 1 | 1 | 33.61 | 72.25 | 0.2428 |
| 106 | 1 | -1 | -1 | -1 | 31.97 | 76.76 | 0.2454 |
| 93 | 1 | -1 | -1 | 1 | 32.19 | 67.69 | 0.2179 |
| 105 | 1 | -1 | 1 | -1 | 29.43 | 85.07 | 0.2504 |
| 101 | 1 | -1 | 1 | 1 | 30.10 | 85.03 | 0.2559 |
| 100 | 1 | 1 | -1 | -1 | 29.72 | 83.77 | 0.2490 |
| 92 | 1 | 1 | -1 | 1 | 35.40 | 56.93 | 0.2015 |
| 97 | 1 | 1 | 1 | -1 | 28.78 | 90.10 | 0.2593 |
| 94 | 1 | 1 | 1 | 1 | 32.25 | 74.76 | 0.2411 |

TABLE 8A (Continued)

DIAGRAM OF FLOTATION SCHEME OF THE FACTORIAL DESIGN TESTS 90 THROUGH 107


Mix 16.67% pulp with modifier, carbonate and add emulsion
Rougher Separation
Rougher Concentrate, (RC)
Rougher Tails, (RT)
1st RC Cleaning
1st Cleaner Tails, (CT$_1$)
1st RT Cleaning
1st Cleaner Concentrate, (CC$_1$)
1st RT Tail, (TT$_1$)
2nd RC Cleaning
2nd Cleaner Tails, (CT$_2$)
1st RT Concentrate (TC$_1$)
2nd Cleaner Concentrate (CC$_2$)
Recleaning of Cleaner Tails
2nd RT Cleaning
Cleaner Tail Concentrate, (SC)
Cleaner Tails, (ST)
2nd RT Concentrate, (TC$_2$)
2nd RT Tail, (TT$_2$)

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 90 LIMESTONE MODIFIED FLYASH PID

| Levels | | |
|---|---|---|
| Levels | A | 60 PPT |
| | B | 5 Min. |
| | C | 1150 RPM |
| | D | 18 Percent |

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |

PRELIMINARY FACTORIAL TEST

NOT SUBMITTED FOR CHEMICAL ANALYSIS

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 91 LIMESTONE MODIFIED FLYASH PID

Levels A 100 PPT
B 10 Min.
C 1700 RPM
D 28 Percent

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |

PRELIMINARY FACTORIAL TEST

NOT SUBMITTED FOR CHEMICAL ANALYSIS

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 92 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

Levels A 100 PPT
B 10 Min.
C 1150 RPM
D 28 Percent

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690435 | $CC_2$ | 63.8 | 22.55 | 49.41 | 39.64 | 12.35 | 16.43 | 1.33 |
| 690436 | SC | 120.8 | 20.70 | 95.79 | 34.26 | 23.94 | 27.58 | 1.15 |
| ------ | RT & ST | 242.7 | 15.83 | 204.30 | 23.59 | 51.07 | 40.45 | 0.79 |
| 690437 | $TT_1$ | 151.9 | 13.83 | 130.89 | 20.65 | 32.72 | 22.68 | 0.69 |
| ------ | $TC_1$ | 90.8 | 19.16 | 73.41 | 28.85 | 18.35 | 17.77 | 0.97 |
| 690438 | $TT_2$ | 31.6 | 14.60 | 26.99 | 21.31 | 6.47 | 4.82 | 0.72 |
| 690439 | $TC_2$ | 59.2 | 21.59 | 46.42 | 33.25 | 11.60 | 12.95 | 1.12 |
| ------ | $CC_2$ & SC & $TC_2$ | 243.8 | 21.41 | 191.61 | 35.40 | 47.90 | 56.93 | 1.19 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 93 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

| | | |
|---|---|---|
| Levels | A | 100 PPT |
| | B | 5 Min. |
| | C | 1150 RPM |
| | D | 28 Percent |

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690440 | $CC_2$ | 94.9 | 21.08 | 74.90 | 36.19 | 18.72 | 22.74 | 1.21 |
| 690441 | SC | 121.3 | 19.29 | 97.90 | 30.76 | 24.47 | 25.27 | 1.03 |
| ------ | RT & ST | 238.8 | 16.93 | 198.39 | 26.86 | 49.59 | 44.72 | 0.90 |
| 690442 | $TT_1$ | 108.5 | 14.52 | 92.75 | 24.28 | 23.18 | 18.89 | 0.82 |
| ------ | $TC_1$ | 130.3 | 18.93 | 105.64 | 29.13 | 26.41 | 25.82 | 0.98 |
| 690444 | $TT_2$ | 33.1 | 15.75 | 27.89 | 26.30 | 6.97 | 06.15 | 0.88 |
| 690443 | $TC_2$ | 97.2 | 20.01 | 77.75 | 30.15 | 19.43 | 19.67 | 1.01 |
| ------ | $CC_2$ & SC & $TC_2$ | 31.34 | 20.06 | 250.55 | 32.19 | 62.63 | 67.69 | 1.08 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 94 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

Levels A 100 PPT
B 10 Min.
C 1700 RPM
D 28 Percent

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 27.79 | | | |
| 690445 | $CC_2$ | 114.8 | 22.09 | 89.44 | 42.26 | 22.36 | 31.71 | 1.42 |
| 690446 | SC | 123.3 | 18.69 | 100.26 | 31.94 | 25.06 | 26.87 | 1.07 |
| ------ | RT & ST | 222.0 | 15.97 | 186.55 | 24.25 | 46.63 | 37.79 | 0.87 |
| 690447 | $TT_1$ | 79.2 | 19.55 | 63.72 | 27.39 | 15.93 | 14.64 | 0.92 |
| ------ | $TC_1$ | 142.8 | 13.91 | 122.83 | 22.63 | 30.70 | 23.33 | 0.76 |
| 690449 | $TT_2$ | 43.1 | 15.76 | 36.31 | 23.50 | 9.07 | 7.16 | 0.79 |
| 690448 | $TC_2$ | 99.7 | 13.22 | 86.52 | 22.27 | 21.63 | 16.16 | 0.75 |
| ------ | $CC_2$ & SC & $TC_2$ | 337.8 | 18.23 | 276.72 | 32.25 | 69.05 | 74.75 | 1.08 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 95 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

| | | |
|---|---|---|
| **Levels** | A | 60 PPT |
| | B | 10 Min. |
| | C | 1150 RPM |
| | D | 28 Percent |

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690452 | $CC_2$ | 55.2 | 14.23 | 47.36 | 22.75 | 11.83 | 9.04 | 0.76 |
| 690453 | SC | 109.0 | 19.86 | 87.35 | 34.43 | 21.83 | 25.23 | 1.16 |
| ------ | RT & ST | 305.7 | 18.83 | 248.16 | 30.39 | 62.04 | 63.29 | 1.02 |
| 690454 | $TT_1$ | 150.8 | 20.72 | 119.55 | 32.38 | 29.88 | 32.48 | 1.09 |
| ------ | $TC_1$ | 154.9 | 16.98 | 128.61 | 28.54 | 32.15 | 30.81 | 0.96 |
| 690456 | $TT_2$ | 68.0 | 19.54 | 54.71 | 32.72 | 13.67 | 15.02 | 1.10 |
| 690455 | $TC_2$ | 86.9 | 14.96 | 73.90 | 25.46 | 18.47 | 15.78 | 0.85 |
| ------ | $CC_2$ & SC & $TC_2$ | 251.1 | 16.93 | 208.6 | 28.60 | 52.15 | 50.06 | 0.96 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 96 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

Levels A 60 PPT
B 10 Min.
C 1150 RPM
D 18 Percent

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690457 | $CC_2$ | 103.3 | 24.79 | 77.69 | 42.26 | 19.42 | 27.55 | 1.42 |
| 690458 | SC | 188.1 | 20.00 | 150.48 | 34.04 | 37.62 | 42.98 | 1.14 |
| ------ | RT & ST | 160.2 | 13.74 | 138.19 | 19.19 | 34.54 | 22.26 | 0.64 |
| 690459 | $TT_1$ | 49.1 | 8.31 | 45.02 | 14.09 | 11.25 | 5.32 | 0.47 |
| ------ | $TC_1$ | 111.1 | 16.14 | 93.17 | 21.66 | 23.29 | 16.93 | 0.73 |
| 690461 | $TT_2$ | 13.0 | 10.19 | 11.68 | 14.09 | 2.92 | 1.38 | 0.47 |
| 690460 | $TC_2$ | 98.1 | 16.93 | 81.49 | 22.75 | 20.37 | 15.55 | 0.76 |
| ------ | $CC_2$ & SC & $TC_2$ | 389.5 | 20.50 | 309.66 | 33.13 | 77.41 | 86.09 | 1.11 |

TABLE 8A (Continued)

EMULSION FLOTATION TEST NO. 97 LIMESTONE MODIFIED FLYASH PID

FACTORIAL DESIGN EXPERIMENT

| | | |
|---|---|---|
| **Levels** | A | 100 PPT |
| | B | 10 Min. |
| | C | 1700 RPM |
| | D | **18 Percent** |

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690462 | $CC_2$ | 207.1 | 19.31 | 167.11 | 29.32 | 41.77 | 41.11 | 0.98 |
| 690463 | SC | 197.8 | 18.23 | 161.74 | 28.75 | 40.43 | 39.02 | 0.97 |
| ------ | RT & ST | 56.5 | 16.64 | 47.10 | 26.64 | 11.77 | 10.53 | 0.89 |
| 690464 | $TT_1$ | 1.5 | 9.42 | 1.36 | 22.18 | 0.34 | 0.25 | 0.74 |
| ------ | $TC_1$ | 55.0 | 16.84 | 45.74 | 26.77 | 11.43 | 10.27 | 0.90 |
| 690466 | $TT_2$ | 1.8 | 13.70 | 1.55 | 24.06 | 0.38 | 0.31 | 0.81 |
| 690465 | $TC_2$ | 53.2 | 16.93 | 44.19 | 26.87 | 11.04 | 9.96 | 0.90 |
| ------ | $CC_2$ & SC & $TC_2$ | 458.1 | 18.57 | 373.04 | 28.78 | 93.26 | 90.10 | 0.96 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 98 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

Levels A 60 PPT
B 5 Min.
C 1150 RPM
D 18 Percent

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690467 | $CC_2$ | 126.3 | 17.99 | 103.58 | 30.45 | 25.89 | 6.46 | 1.02 |
| 690468 | SC . | 187.3 | 18.30 | 153.02 | 30.72 | 38.25 | 39.45 | 1.03 |
| ------ | RT & ST | 145.1 | 16.95 | 120.52 | 28.23 | 30.13 | 28.56 | 0.95 |
| 690469 | $TT_1$ | 33.2 | 16.36 | 27.77 | 27.83 | 6.94 | 6.48 | 0.93 |
| ------ | $TC_1$ | 111.9 | 17.12 | 92.75 | 28.26 | 23.18 | 22.07 | 0.95 |
| 690471 | $TT_2$ | 15.3 | 16.79 | 12.73 | 26.73 | 3.18 | 2.85 | 0.90 |
| 690470 | $TC_2$ | 96.6 | 17.16 | 80.02 | 28.62 | 20.00 | 19.22 | 0.96 |
| ------ | $CC_2$ & SC & $TC_2$ | 410.2 | 17.94 | 336.62 | 30.13 | 84.15 | 85.13 | 1.01 |

### TABLE 8A (Continued)

### EMULSION FLOTATION TEST NO. 99 LIMESTONE MODIFIED FLYASH PID

### FACTORIAL DESIGN EXPERIMENT

Levels A 60 PPT
B 5 Min.
C 1700 RPM
D 28 Percent

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690472 | $CC_2$ | 126.4 | 20.59 | 100.37 | 34.70 | 25.09 | 29.22 | 1.16 |
| 690473 | SC | 137.8 | 19.05 | 111.55 | 33.07 | 27.88 | 30.95 | 1.11 |
| ------ | RT & ST | 192.8 | 14.89 | 164.11 | 23.31 | 41.02 | 32.11 | 0.78 |
| 690474 | $TT_1$ | 71.5 | 13.46 | 61.88 | 20.70 | 15.47 | 10.74 | 0.69 |
| ------ | $TC_1$ | 121.3 | 15.73 | 102.23 | 24.89 | 25.55 | 21.36 | 0.84 |
| 690476 | $TT_2$ | 23.3 | 13.71 | 20.11 | 70.65 | 5.02 | 3.48 | 0.69 |
| 690475 | $TC_2$ | 98.0 | 16.20 | 82.12 | 25.94 | 20.53 | 17.87 | 0.87 |
| ------ | $CC_2$ & SC & $TC_2$ | 362.2 | 18.82 | 294.04 | 31.63 | 73.51 | 78.06 | 1.06 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 100 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

Levels A 100 PPT
B 10 Min.
C 1150 RPM
D 18 Percent

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690477 | $CC_2$ | 97.8 | 20.07 | 78.17 | 34.57 | 19.54 | 22.67 | 1.16 |
| 690478 | SC | 176.1 | 18.85 | 142.91 | 29.80 | 35.72 | 35.73 | 1.00 |
| ------ | RT & ST | 194.9 | 19.04 | 152.80 | 25.79 | 39.45 | 34.16 | 0.87 |
| 690479 | $TT_1$ | 40.3 | 20.57 | 32.01 | 24.81 | 8.00 | 6.66 | 0.83 |
| ------ | $TC_1$ | 154.6 | 18.64 | 125.79 | 26.05 | 31.44 | 27.50 | 0.87 |
| 690481 | $TT_2$ | 13.4 | 17.43 | 11.06 | 23.06 | 2.76 | 2.14 | 0.77 |
| 690480 | $TC_2$ | 141.2 | 18.75 | 114.73 | 26.34 | 28.68 | 26.34 | 0.88 |
| ------ | $CC_2$ & SC & $TC_2$ | 415.1 | 19.13 | 335.81 | 29.72 | 83.95 | 83.77 | 1.00 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 101 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

| **Levels** | | |
|---|---|---|
| | A | 100 PPT |
| | B | 5 Min. |
| | C | 1700 RPM |
| | D | 28 Percent |

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 6904892 | $CC_2$ | 143.0 | 20.60 | 113.54 | 32.38 | 28.38 | 32.36 | 1.09 |
| 690483 | SC | 136.6 | 20.83 | 108.15 | 31.80 | 27.03 | 31.80 | 1.07 |
| ------ | RT & ST | 195.1 | 19.18 | 157.69 | 25.12 | 39.42 | 33.24 | 0.84 |
| 690484 | $TT_1$ | 29.9 | 15.36 | 25.30 | 22.92 | 6.32 | 4.86 | 0.77 |
| ------ | $TC_1$ | 165.2 | 19.87 | 132.39 | 25.54 | 33.09 | 28.38 | 0.86 |
| 690486 | $TT_2$ | 21.0 | 4.87 | 17.46 | 20.92 | 4.36 | 3.06 | 0.70 |
| 690485 | $TC_2$ | 144.2 | 20.30 | 114.93 | 26.25 | 28.73 | 25.31 | 0.88 |
| ------ | $CC_2$ & SC & $TC_2$ | 423.8 | 20.58 | 336.62 | 30.10 | 84.15 | 85.03 | 1.01 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 102 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

| Levels | | |
|---|---|---|
| | A | 60 PPT |
| | B | 5 Min. |
| | C | 1150 RPM |
| | D | 28 Percent |

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 6790487 | $CC_2$ | 112.7 | 23.93 | 85.81 | 39.86 | 21.45 | 28.70 | 1.34 |
| 690488 | SC | 128.7 | 19.38 | 103.76 | 31.33 | 25.94 | 27.28 | 1.05 |
| ------ | RT & ST | 223.1 | 16.05 | 187.31 | 22.30 | 46.82 | 35.06 | 0.75 |
| 690489 | $TT_1$ | 87.4 | 16.16 | 73.28 | 19.46 | 18.32 | 11.96 | 0.65 |
| ------ | $TC_1$ | 135.7 | 15.97 | 114.03 | 24.13 | 28.50 | 23.59 | 0.81 |
| 690491 | $TT_2$ | 64.2 | 14.28 | 55.03 | 20.74 | 13.75 | 9.57 | 0.70 |
| 690490 | $TC_2$ | 71.5 | 17.48 | 59.00 | 27.30 | 14.75 | 13.57 | 0.92 |
| ------ | $CC_2$ & SC & $TC_2$ | 313.0 | 20.59 | 248.57 | 33.31 | 62.14 | 69.50 | 1.11 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 103 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

**Levels** **A** **60 PPT**
**B** **10 Min.**
**C** **1700 RPM**
**D** **18 Percent**

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690492 | $CC_2$ | 129.1 | 22.49 | 100.07 | 37.80 | 25.01 | 31.74 | 1.27 |
| 690493 | SC | 128.6 | 18.56 | 104.73 | 31.24 | 26.18 | 27.45 | 1.05 |
| ------ | RT & ST | 198.6 | 14.70 | 169.42 | 21.96 | 42.36 | 31.23 | 0.73 |
| 690494 | $TT_1$ | 39.4 | 13.88 | 33.93 | 18.55 | 8.48 | 5.28 | 0.62 |
| ------ | $TC_1$ | 159.2 | 14.90 | 135.49 | 22.82 | 33.87 | 25.95 | 0.77 |
| 690496 | $TT_2$ | 24.3 | 14.35 | 20.81 | 19.86 | 5.20 | 3.46 | 0.67 |
| 690495 | $TC_2$ | 134.9 | 14.99 | 114.68 | 23.36 | 28.67 | 22.48 | 0.78 |
| ------ | $CC_2$ & SC & $TC_2$ | 392.6 | 18.63 | 319.46 | 30.46 | 79.87 | 81.68 | 1.02 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 104 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

Levels A 60 PPT
B 10 Min.
C 1700 RPM
D 18 Percent

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690497 | $CC_2$ | 115.6 | 23.87 | 88.01 | 40.25 | 22.00 | 29.72 | 1.35 |
| 690498 | SC | 100.3 | 20.90 | 79.34 | 33.51 | 19.83 | 22.31 | 1.12 |
| ------ | RT & ST | 238.8 | 15.02 | 202.94 | 22.67 | 50.73 | 38.62 | 0.76 |
| 690499 | $TT_1$ | 103.8 | 12.11 | 91.23 | 19.71 | 22.80 | 15.09 | 0.66 |
| ------ | $TC_1$ | 135.0 | 17.26 | 111.71 | 25.10 | 27.92 | 23.53 | 0.84 |
| 690501 | $TT_2$ | 26.1 | 12.22 | 22.91 | 17.28 | 5.72 | 3.32 | 0.58 |
| 690500 | $TC_2$ | 108.9 | 18.46 | 88.80 | 27.12 | 22.20 | 20.21 | 0.91 |
| ------ | $CC_2$ & SC & $TC_2$ | 324.8 | 21.14 | 256.15 | 33.61 | 64.03 | 72.25 | 1.13 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 105 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

**Levels** A 100 PPT
B 5 Min.
C 1700 RPM
D 18 Percent

| Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690502 | $CC_2$ | 156.2 | 19.88 | 125.15 | 32.07 | 31.28 | 33.68 | 1.08 |
| 690503 | SC | 150.4 | 19.16 | 121.58 | 30.23 | 30.39 | 30.84 | 1.01 |
| ------ | RT & ST | 153.5 | 16.43 | 128.29 | 22.37 | 32.07 | 24.09 | 0.75 |
| 690504 | $TT_1$ | 23.4 | 9.67 | 21.14 | 13.30 | 5.28 | 2.35 | 0.45 |
| ------ | $TC_1$ | 130.1 | 17.65 | 107.15 | 24.16 | 26.78 | 21.73 | 0.81 |
| 690506 | $TT_2$ | 10.8 | 12.61 | 9.44 | 14.92 | 2.36 | 1.18 | 0.50 |
| 690505 | $TC_2$ | 119.3 | 18.10 | 97.71 | 25.06 | 24.42 | 20.54 | 0.84 |
| ------ | $CC_2$ & SC & $TC_2$ | 425.9 | 19.13 | 344.44 | 29.43 | 86.11 | 85.07 | 0.99 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 106 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

Levels A 100 PPT
B 5 Min.
C 1150 RPM
D 18 Percent

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690507 | $CC_2$ | 99.7 | 22.15 | 77.62 | 38.50 | 19.40 | 25.07 | 1.29 |
| 690508 | SC | 173.3 | 19.35 | 139.77 | 30.76 | 34.94 | 36.08 | 1.03 |
| ------ | RT & ST | 180.4 | 15.66 | 152.15 | 22.01 | 38.02 | 28.10 | 0.74 |
| 690509 | $TT_1$ | 85.8 | 14.63 | 73.25 | 17.98 | 18.31 | 11.05 | 0.60 |
| ------ | $TC_1$ | 94.6 | 16.60 | 78.90 | 25.75 | 19.72 | 17.05 | 0.86 |
| 690511 | $TT_2$ | 11.7 | 12.59 | 10.23 | 16.88 | 2.55 | 1.44 | 0.57 |
| 690510 | $TC_2$ | 82.9 | 12.16 | 68.67 | 27.08 | 17.16 | 15.60 | 0.91 |
| ------ | $CC_2$ & SC & $TC_2$ | 355.9 | 19.63 | 286.06 | 31.97 | 71.51 | 76.76 | 1.07 |

## TABLE 8A (Continued)

## EMULSION FLOTATION TEST NO. 107 LIMESTONE MODIFIED FLYASH PID

## FACTORIAL DESIGN EXPERIMENT

Levels A 60 PPT
B 5 Min.
C 1700 RPM
D 18 Percent

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690512 | $CC_2$ | 103.8 | 23.88 | 79.01 | 40.69 | 19.75 | 26.97 | 1.37 |
| 690513 | SC | 107.8 | 21.35 | 84.78 | 32.02 | 21.19 | 22.78 | 1.07 |
| ------ | RT & ST | 241.4 | 14.48 | 206.46 | 23.28 | 51.61 | 40.33 | 0.78 |
| 690514 | $TT_1$ | 101.1 | 9.79 | 91.20 | 17.94 | 22.80 | 13.73 | 0.60 |
| ------ | $TC_1$ | 140.3 | 17.85 | 115.26 | 27.50 | 28.81 | 26.60 | 0.92 |
| 690516 | $TT_2$ | 45.3 | 13.13 | 39.35 | 21.08 | 9.83 | 9.69 | 0.70 |
| 690515 | $TC_2$ | 95.0 | 20.10 | 75.91 | 30.84 | 18.97 | 19.64 | 1.03 |
| ------ | $CC_2$ & SC & $TC_2$ | 306.6 | 21.82 | 239.70 | 34.50 | 59.92 | 69.40 | 1.16 |

## TABLE 9A

## EMULSION FLOTATION TEST NO. 108 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 20 ml 10,000 PPM FAS added, stirred for 5 minutes.
2. 400 grams of PID added, conditioned at 2400 RPM for 15 minutes, carbonated to pH 10.0, added 4.0 PPT emulsion.
3. Conditioned for 7.5 minutes at 1700 RPM, floated for four minutes, recleaned concentrate twice.
4. Scavanged cleaner tails with additional 20 PPT emulsion for 2 minutes.
5. Recleaned RT & ST twice at 1200 RPM for 2 minutes.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690561 | $CC_2$ | 84.0 | 21.36 | 66.06 | 25.31 | 16.59 | 19.57 | 1.19 |
| 690562 | SC | 145.0 | 19.81 | 116.28 | 32.11 | 29.07 | 31.33 | 1.08 |
| ------ | RT & ST | 230.0 | 16.73 | 191.54 | 25.98 | 47.88 | 41.76 | 0.87 |
| 690563 | $TT_1$ | 86.0 | 14.18 | 73.81 | 23.06 | 18.45 | 14.28 | 0.77 |
| ------ | $TC_1$ | 144.0 | 18.25 | 118.73 | 27.81 | 29.43 | 27.48 | 0.83 |
| 690564 | $TT_2$ | 10.0 | 13.63 | 8.64 | 22.23 | 2.16 | 1.61 | 0.75 |
| 690565 | $TC_2$ | 134.0 | 18.59 | 109.09 | 28.26 | 27.27 | 25.87 | 0.95 |
| ------ | $CC_2$ & SC & $TC_2$ | 363.0 | 19.72 | 291.43 | 31.39 | 72.85 | 76.77 | 1.05 |

## TABLE 10A

## EMULSION FLOTATION TEST NO. 109 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 20 ml 10,000 PPM FAS added, stirred for 5 minutes.
2. 400 grams of PID added, conditioned at 2400 RPM for 15 minutes, carbonated to pH 10.0, added 4.0 PPT emulsion.
3. Conditioned for 3.5 minutes, floated for four minutes at 1621 RPM.
4. Recleaned concentrate twice, combined the $CT_1$ and $CT_2$ fractions and added 20.0 PPT of emulsion, floated at 1700 RPM for 2 minutes.
5. Combined the ST & RT, added 20.0 PPT emulsion, floated for 2 minutes, recleaned twice.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690566 | $CC_2$ | 86.8 | 24.07 | 65.91 | 41.17 | 16.47 | 22.77 | 1.38 |
| 690567 | SC | 13.28 | 20.59 | 105.46 | 32.34 | 26.36 | 28.62 | 1.09 |
| ------ | RT & ST | 230.6 | 11.56 | 203.95 | 22.68 | 50.98 | 38.82 | 0.76 |
| 690568 | $TT_1$ | 70.2 | 12.74 | 61.26 | 17.01 | 15.31 | 8.74 | 0.57 |
| ------ | $TC_1$ | 160.4 | 11.05 | 142.69 | 25.12 | 35.67 | 30.08 | 0.84 |
| 690569 | $TT_2$ | 37.8 | 14.05 | 32.49 | 19.25 | 8.12 | 5.24 | 0.65 |
| 690570 | $TC_2$ | 132.6 | 16.89 | 110.20 | 26.85 | 27.55 | 24.83 | 0.90 |
| ------ | $CC_2$ & SC<br>$TC_2$ | 352.2 | 20.06 | 281.57 | 32.25 | 70.39 | 76.22 | 1.08 |

## TABLE 11A

## EMULSION FLOTATION TEST NO. 110 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 20 ml 10,000 PPM FAS added, stirred for 5 minutes.
2. 400 grams of PID added, conditioned at 2400 RPM for 15 minutes, carbonated to pH 10.0, added 4.0 PPT emulsion.
3. Conditioned for 7.5 minutes at 1700 RPM, floated for four minutes, recleaned concentrate twice.
4. Scavanged cleaner tails with additional 20 PPT emulsion for 2 minutes.
5. Recleaned RT & ST twice at 1200 RPM for 2 minutes.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690577 | $CC_2$ | 155.0 | 13.77 | 133.66 | 29.75 | 33.41 | 33.36 | 1.00 |
| 690578 | SC | 147.0 | 16.84 | 122.25 | 28.11 | 30.56 | 28.83 | 0.94 |
| ------ | RT & ST | 147.0 | 16.98 | 122.04 | 27.31 | 30.51 | 27.97 | 0.92 |
| 690579 | $TT_1$ | 22.5 | 17.01 | 18.67 | 27.78 | 4.66 | 4.35 | 0.93 |
| 690580 | $TC_1$ | 124.5 | 16.97 | 103.37 | 27.23 | 25.84 | 23.61 | 0.91 |
| ------ | $CC_2$ & SC | 302.0 | 15.27 | 255.9 | 28.96 | 63.97 | 62.20 | 0.92 |

## TABLE 12A

### EMULSION FLOTATION TEST NO. 111 LIMESTONE MODIFED FLYASH PID

1. 2000 ml $H_2O$ added, 20 ml 10,000 PPM added, stirred

2. 400 grams PID flyash added, conditioned for 15 minutes, carbonated to pH 10.0, added 10 PPT, 15 Percent rosin emulsion carbonated on to pH 7.0

3. Conditioned 3.5 minutes, floated for 4 minutes at 1700 RPM, concentrate recleaned twice.

4. $CT_1$ & $CT_2$ combined, 5.0 PPT emulsion added, conditioned 3.5 minutes and floated 2 minutes.

5. ST & RT combined, 5.0 PPT Emulsion added, conditioned 3.5 minutes, floated 2 minutes, recleaned twice.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690581 | $CC_2$ | 97.0 | 27.35 | 70.47 | 49.74 | 17.61 | 29.41 | 1.67 |
| 690582 | SC | 77.5 | 21.72 | 60.67 | 39.72 | 15.16 | 20.22 | 1.33 |
| ------ | RT & ST | 284.0 | 11.13 | 252.40 | 19.82 | 63.10 | 41.99 | 0.67 |
| 690583 | $TT_1$ | 142.0 | 8.42 | 130.04 | 15.84 | 32.51 | 17.28 | 0.53 |
| ------ | $TC_1$ | 142.0 | 13.84 | 122.36 | 24.06 | 30.59 | 24.70 | 0.81 |
| 690584 | $TT_2$ | 60.5 | 11.18 | 53.74 | 19.82 | 13.43 | 8.93 | 0.67 |
| 690585 | $TC_2$ | 81.5 | 15.81 | 68.62 | 27.39 | 18.15 | 15.77 | 0.92 |
| ------ | $CC_2$ & SC & $TC_2$ | 256.0 | 21.97 | 199.76 | 39.01 | 49.94 | 65.40 | 1.31 |
| ------ | $CC_2$ & SC | 174.5 | 248.85 | 131.14 | 45.10 | 32.77 | 49.63 | 1.52 |

## TABLE 13A

## EMULSION FLOTATION TEST NO. 112 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added, 20 ml of 10,000 PPM FAS added, stirred.

2. 400 grams PID added, conditioned for 15 minutes, carbonated to pH 10.0, added 10.0 PPT emulsion, carbonated on to pH 7.0.

3. Conditioned for 3.5 minutes, floated 4 minutes at 1700 RPM, recleaned concentrate twice.

4. Combined $CT_1$ & $CT_2$, added 5 PPT emulsion, conditioned for 3.5 minutes, floated 2.0 minutes.

5. Combined ST & RT, added 5 PPT emulsion, conditioned for 3.5 minutes, floated 2 minutes, recleaned concentrate twice.

6. Emulsion altered to 0.5% sodium alkylarylsulfonate, 23.5% tall oil, 26% fuel oil, 50.0% $H_2O$.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |

NOT SUBMITTED FOR CHEMICAL ANALYSIS

## TABLE 14A

## EMULSION FLOTATION TEST NO. 113 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added, 20 ml of 10,000 PPM FAS added, stirred.
2. 400 grams PID added, conditioned for 15 minutes, carbonated to pH 10.0, added 10.0 PPT emulsion, carbonated on to pH 7.0.
3. Conditioned for 3.5 minutes, floated 4 minutes at 1700 RPM, recleaned concentrate twice.
4. Combined $CT_1$ & $CT_2$, added 5 PPT emulsion conditioned for 3.5 minutes, floated 2.0 minutes.
5. Combined ST & RT, added 5 PPT emulsion conditioned for 3.5 minutes, floated 2 minutes, recleaned concentrate twice.
6. Emulsive altered to 1.5% sodium alkyarylsulfonate, 23.5% tall oil, 25% fuel oil, 50% $H_2O$.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690623 | $CC_2$ | 46.0 | 26.74 | 33.70 | 52.24 | 8.42 | 14.77 | 1.75 |
| 690624 | SC | 68.0 | 23.40 | 52.09 | 45.85 | 13.02 | 20.04 | 1.54 |
| ------ | RT & ST | 339.0 | 13.00 | 294.94 | 23.54 | 73.73 | 64.63 | 0.79 |
| 690625 | $TT_1$ | 175.0 | 10.47 | 156.68 | 19.51 | 39.17 | 25.65 | 0.65 |
| ------ | $TC_1$ | 164.0 | 15.70 | 138.26 | 28.12 | 34.56 | 38.98 | 0.94 |
| 690626 | $TT_2$ | 88.0 | 13.69 | 75.95 | 24.68 | 18.98 | 18.74 | 0.83 |
| 690627 | $TC_2$ | 76.0 | 18.01 | 62.31 | 32.33 | 15.57 | 20.14 | 1.09 |
| ------ | $CC_2$ & SC & $TC_2$ | 190.0 | 22.06 | 148.10 | 41.61 | 37.02 | 54.95 | 1.40 |

## TABLE 15A

## EMULSION FLOTATION TEST NO. 114 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added, 20 ml of 10,000 PPM FAS added, stirred.
2. 400 grams PID added, conditioned for 15 minutes, carbonated to pH 10.0, added 10.0 PPT emulsion, carbonated on to pH 7.0.
3. Conditioned for 3.5 minutes, floated 4 minutes at 1700 RPM, recleaned concentrate twice.
4. Combined $CT_1$ & $CT_2$, added 5 PPT emulsion, conditioned for 3.5 minutes, floated 2.0 minutes.
5. Combined ST & RT, added 5 PPT emulsion, conditioned for 3.5 minutes, floated 2 minutes, recleaned concentrate twice.
6. Emulsive altered to 2.0 sodium alkyarylsulfonate,12.59% L-5 tall oil, 10.5% M-28 tall oil, 25.0% fuel oil, 50.0% $H_2O$.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690628 | $CC_2$ | 64.0 | 25.85 | 47.46 | 49.53 | 11.86 | 19.72 | 1.66 |
| 690629 | SC | 55.0 | 22.17 | 42.81 | 41.82 | 10.70 | 15.02 | 1.40 |
| ------ | RT & ST | 333.0 | 13.38 | 288.47 | 23.12 | 72.11 | 55.96 | 0.78 |
| 690630 | $TT_1$ | 134.0 | 10.21 | 120.32 | 17.37 | 30.08 | 17.53 | 0.58 |
| ------ | $TC_1$ | 199.0 | 15.51 | 168.15 | 27.24 | 42.03 | 38.43 | 0.91 |
| 690631 | $TT_2$ | 93.0 | 12.63 | 81.25 | 21.21 | 20.31 | 14.73 | 0.73 |
| 690632 | $TC_2$ | 106.0 | 18.02 | 86.90 | 32.51 | 21.72 | 23.70 | 1.09 |
| ------ | $CC_2$ & SC & $TC_2$ | 225.0 | 21.26 | 177.17 | 39.31 | 44.29 | 58.44 | 1.32 |

## TABLE 16A

## EMULSION FLOTATION TEST NO. 115 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added, 20 ml 10,000 PPM FAS added, stirred.

2. 400 grams PID flyash added, conditioned for 1.0 hour, carbonated to pH 6.5 , added 10.0 PPT emulsion, conditioned for 3.5 minutes, floated at 1700 RPM for 4 minutes, concentrate recleaned twice.

3. $CT_1$ & $CT_2$ combined, 5 PPT emulsion added, conditioned for 3.5 minutes, floated 2 minutes.

4. ST & RT combined, 5 PPT emulsion added, conditioned for 3.5 minutes, floated 2 minutes.

5. Concentrate recleaned twice.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690551 | $CC_2$ | 9.2 | 35.65 | 5.92 | 81.45 | 1.48 | 4.04 | 2.73 |
| 690652 | SC | 25.0 | 29.07 | 17.73 | 61.60 | 4.43 | 9.16 | 2.07 |
| ------ | RT & ST | 439.7 | 16.20 | 368.49 | 27.36 | 92.12 | 84.58 | 0.91 |
| 690653 | $TT_1$ | 115.0 | 18.86 | 93.31 | 32.09 | 23.32 | 25.12 | 1.08 |
| ------ | $TC_1$ | 324.7 | 15.26 | 275.18 | 25.75 | 68.79 | 59.46 | 0.86 |
| 690654 | $TT_2$ | 243.0 | 14.27 | 208.32 | 24.36 | 52.08 | 42.58 | 0.82 |
| 690655 | $TC_2$ | 81.7 | 18.16 | 66.86 | 30.10 | 16.71 | 16.88 | 1.01 |
| ------ | $CC_2$ & SC & $TC_2$ | 115.9 | 21.91 | 90.51 | 39.62 | 22.62 | 30.08 | 1.33 |
| ------ | $CC_2$ & SC | 34.2 | 308.5 | 23.65 | 66.56 | 5.91 | 13.20 | 2.23 |

## TABLE 17A

### EMULSION FLOTATION TEST NO. 116 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added, 20 ml of 10,000 PPM FAS added, stirred.

2. 400 grams PID added, conditioned for 15 minutes, carbonated to pH 6.5, 10.0 PPT emulsion added, floated 4 minutes.

3. $CT_1$ & $CT_2$ combined, 5.0 PPT emulsion added, conditioned 3.5 minutes, floated 2 minutes.

4. ST & RT combined, 5.0 PPT emulsion added, conditioned 3.5 minutes, floated 2 minutes, recleaned twice.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690659 | $CC_2$ | 125.0 | 22.08 | 97.40 | 39.51 | 24.35 | 32.29 | 1.33 |
| 690660 | SC | 97.7 | 19.02 | 79.12 | 32.95 | 19.78 | 21.87 | 1.11 |
| ------ | RT & ST | 123.3 | 13.14 | 150.53 | 22.04 | 37.63 | 27.83 | 0.74 |
| 690661 | $TT_1$ | 23.8 | 10.91 | 21.20 | 18.81 | 5.30 | 3.34 | 0.63 |
| ------ | $TC_1$ | 149.5 | 13.50 | 129.33 | 22.57 | 32.33 | 24.49 | 0.76 |
| 690663 | $TT_2$ | 16.5 | 12.08 | 74.50 | 19.87 | 3.62 | 2.41 | 0.67 |
| 690662 | $TC_2$ | 133.0 | 13.66 | 114.83 | 22.92 | 28.70 | 22.08 | 0.77 |
| ------ | $CC_2$ & SC & $TC_2$ | 355.7 | 18.10 | 291.35 | 31.18 | 72.83 | 76.24 | 1.05 |
| ------ | $CC_2$ & SC | 222.7 | 20.74 | 176.52 | 36.56 | 44.13 | 54.16 | 1.23 |

## TABLE 18A

## EMULSION FLOTATION TEST NO. 117 DOLOMITE MODIFIED FLYASH CI

1. 2000 ml $H_2O$ added, 20 ml of 10,000 PPM FAS, stirred.

2. 400 grams CI flyash added, conditioned for 15 minutes, carbonated to pH 7.0, 10.0 PPT emulsion added, conditioned for 3.5 minutes, floated 4 minutes.

3. 10.0 PPT emulsion added to RT, conditioned for 3.5 minutes, RT refloated for 5.5 minutes.

4. Concentrate recleaned for 3 minutes.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 3.79 | 384.12 | 22.97 | | | |
| 690678 | CC | 94.0 | 24.73 | 70.75 | 26.47 | 18.41 | 21.22 | 1.15 |
| 690679 | CT | 105.0 | 25.80 | 77.91 | 27.83 | 20.28 | 24.57 | 1.21 |
| 690680 | 1st 4 min. RC | 70.0 | 26.10 | 51.73 | 30.32 | 13.46 | 17.77 | 1.31 |
| 690681 | RT | 178.0 | 25.23 | 133.09 | 25.95 | 34.64 | 39.14 | 1.13 |

## TABLE 19A

## EMULSION FLOTATION TEST NO. 118 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 20 ml of 10,000 PPM FAS, stirred.
2. 400 grams PID added, conditioned for 15 minutes, carbonated to pH 9.0 at 1100 RPM, added 20.0 PPT emulsion, carbonated on to pH 6.5.
3. Continued carbonation for 15 minutes, stopped and checked slurry, continued carbonation for 15 more minutes, floated 5 minutes.
4. Recleaned RC for 5 minutes.

| Log Number | Fraction | Wt. Rec. Gms | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 690751 | RT | 269.0 | 14.35 | 230.39 | 23.36 | 57.59 | 45.16 | 0.78 |
| ------ | RC | 187.0 | 23.49 | 143.09 | 38.76 | 35.77 | 46.54 | 1.30 |
| 690750 | CT | 127.0 | 21.79 | 99.33 | 35.66 | 24.83 | 29.72 | 1.20 |
| 690749 | CC | 60.0 | 28.07 | 43.76 | 45.81 | 10.94 | 16.82 | 1.54 |

## TABLE 20A

## EMULSION FLOTATION TEST NO. 119 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 20.0 PPT 10,000 PPM FAS added, stirred.

2. 400 grams PID added, conditined for 15 minutes, carbonated to pH 6.5, 10.0 PPT emulsion added, conditioned for 3.5 minutes, floated 4 minutes.

3. Recleaned RC twice and each tail fraction separately.

4. RT recarbonated back to pH 6.5 before floated, emulsion split proportionately, floated and recleaned twice.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| ------ | RT | 346.0 | 15.16 | 293.55 | 25.42 | 73.38 | 62.63 | 0.85 |
| 690757 | $TT_1$ | 244.0 | 12.57 | 213.33 | 21.53 | 53.33 | 38.54 | 0.72 |
| ------ | $TC_1$ | 102.0 | 21.36 | 80.22 | 35.79 | 20.05 | 24.09 | 1.20 |
| 690758 | $TT_2$ | 61.5 | 16.97 | 51.06 | 28.48 | 12.76 | 12.20 | 0.96 |
| 690759 | $TC_2$ | 40.5 | 28.01 | 29.16 | 48.61 | 7.29 | 11.89 | 1.63 |
| ------ | RC | 10.7 | 25.48 | 79.74 | 44.83 | 19.93 | 29.37 | 1.50 |
| ------ | $CT_1$ | 55.5 | 22.98 | 42.75 | 40.29 | 10.68 | 14.45 | 1.35 |
| 690753 | CC of $CT_1$ | 20.5 | 28.15 | 14.73 | 52.37 | 3.68 | 6.47 | 1.76 |
| 690754 | CT of $CT_1$ | 35.0 | 19.93 | 28.02 | 33.95 | 7.00 | 7.98 | 1.14 |
| ------ | $CC_1$ | 51.5 | 28.18 | 36.99 | 50.07 | 9.24 | 15.52 | 1.68 |
| 690752 | $CC_2$ | 19.5 | 32.42 | 13.18 | 60.03 | 3.29 | 6.63 | 2.02 |
| ------ | $CT_2$ | 32.0 | 25.60 | 23.81 | 44.55 | 5.95 | 8.89 | 1.50 |
| 690755 | CC of $CT_2$ | 16.5 | 28.58 | 11.78 | 51.45 | 2.94 | 5.09 | 1.73 |
| 690756 | CT of $CT_2$ | 15.5 | 22.41 | 12.03 | 37.72 | 3.00 | 3.80 | 1.27 |
| ------ | $CC_2$, CC of $CT_1$, CC of $CT_2$, $TC_2$ | 97.0 | 29.03 | 68.85 | 52.10 | 17.21 | 30.10 | 1.75 |

## TABLE 21A

## AGGLOMERATE FLOTATION TEST NO. 120 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 20.0 PPT 10,000 PPM FAS added, stirred.

2. 400 grams PID added, conditioned for 15 minutes, carbonated to pH 6.5 and allowed to come back to pH 9.0. Then 10.0 PPT emulsion added, condtioned for 3.5 minutes, floated 4 minutes.

3. Recleaned RC twice and end tail fraction separately.

4. RT recarbonated back to pH 6.5 and 5 PPT emulsion added, floated and recleaned twice.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| ------ | Feed | 400 | 1.03 | 395.88 | 29.79 | ----- | ----- | ---- |
| ------ | RC | 131.0 | 24.26 | 99.23 | 40.45 | 24.80 | 33.65 | 1.36 |
| ------ | $CT_1$ | 81.0 | 22.20 | 63.02 | 37.32 | 15.75 | 19.72 | 1.25 |
| 690761 | CC of $CT_1$ | 27.0 | 23.05 | 20.78 | 39.22 | 5.19 | 6.83 | 1.32 |
| 690762 | CT of $CT_1$ | 54.0 | 21.77 | 42.24 | 36.39 | 10.56 | 12.89 | 1.22 |
| ------ | $CC_1$ | 50.0 | 27.58 | 36.21 | 45.90 | 9.05 | 13.93 | 1.54 |
| 690760 | $CC_2$ | 32.0 | 28.02 | 23.03 | 47.91 | 5.75 | 9.25 | 1.61 |
| ------ | $CT_2$ | 18.0 | 26.78 | 13.18 | 42.39 | 3.29 | 4.68 | 1.42 |
| 690763 | CC of $CT_2$ | 7.0 | 26.77 | 5.13 | 42.88 | 1.28 | 1.84 | 1.44 |
| 690764 | CT of $CT_2$ | 11.0 | 26.82 | 8.05 | 42.09 | 2.01 | 2.84 | 1.41 |
| ------ | RT | 324.0 | 15.09 | 275.13 | 25.80 | 68.78 | 59.57 | 0.86 |
| 690765 | $TT_1$ | 205.0 | 12.74 | 178.88 | 23.02 | 44.72 | 34.55 | 0.77 |
| ------ | $TC_1$ | 119.0 | 19.12 | 96.25 | 30.98 | 24.06 | 25.02 | 1.04 |
| 690766 | $TT_2$ | 70.0 | 16.63 | 58.35 | 27.30 | 14.58 | 13.36 | 0.92 |
| 690767 | $TC_2$ | 49.0 | 22.66 | 37.90 | 36.67 | 9.47 | 11.66 | 1.23 |
| ------ | $CC_2$,CC of $CT_1$<br>CC of $CT_2$,$TC_2$ | 115.0 | 24.45 | 86.84 | 40.62 | 21.71 | 29.58 | 1.36 |

## TABLE 22A

## EMULSION FLOTATION TEST NO. 121 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 1.0 PPT 10,000 PPM FAS added, stirred.

2. 400 grams PID flyash added, conditioned for one hour at 1700 RPM, carbonated to pH 6.5, 5.0 PPT emulsion added, conditioned for 3.5 minutes at 1900 RPM.

3. Rougher separation at 1900 RPM for 4 minutes, recleaned RC & $CC_1$ for 2 minutes.

4. Combined RT, $CT_1$ & $CT_2$ and repeated Step 3 - 3 times.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |

TEST ABORTED

NOT SUBMITTED FOR CHEMICAL ANALYSIS

## TABLE 23A

### AGGLOMERATE FLOTATION TEST NO. 122 LIMESTONE WET COLLECTED KPL

1. 2150 ml KPL slurry added to flotation cell, 12 ml of FAS added, conditioned for 15 minutes.

2. Carbonated to pH 7.4 at 2400 RPM, 10 PPT emulsion added, floated 4 minutes, RC recleaned twice.

3. $CT_1$ recleaned with additional 2.5 PPT emulsion for 2 minutes.

4. RT recleaned twice after recarbonation to pH 7.4, additional 5.0 PPT emulsion added before float.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| ------ | Feed | 249.2 | ----- | ------ | 27.13 | ----- | ----- | ---- |
| ------ | RC | 19.5 | 15.03 | 16.57 | 37.25 | 7.36 | 9.12 | 1.37 |
| ------ | $CC_1$ | 5.9 | 15.60 | 4.98 | 38.46 | 2.21 | 2.83 | 1.42 |
| 690837 | $CC_2$ | 2.0 | 16.62 | 1.67 | 40.03 | 0.74 | 0.98 | 1.48 |
| 690839 | $CT_2$ | 3.9 | 15.10 | 3.31 | 37.67 | 1.47 | 1.84 | 1.39 |
| ------ | $CT_1$ | 13.6 | 14.78 | 11.59 | 36.74 | 5.15 | 6.29 | 1.35 |
| 690838 | CC of $CT_1$ | 2.5 | 15.94 | 2.10 | 38.46 | 0.93 | 1.19 | 1.42 |
| 690840 | CT of $CT_1$ | 11.1 | 14.47 | 9.49 | 36.36 | 4.22 | 5.10 | 1.34 |
| ------ | RT | 229.7 | 9.33 | 208.29 | 27.27 | 92.63 | 84.01 | 1.01 |
| 690842 | $TT_1$ | 203.9 | 8.93 | 185.69 | 26.69 | 82.58 | 73.30 | 0.98 |
| ------ | $TC_1$ | 25.8 | 12.41 | 22.60 | 32.09 | 10.05 | 10.72 | 1.18 |
| 690843 | $TT_2$ | 20.4 | 11.62 | 18.03 | 30.85 | 8.01 | 8.22 | 1.14 |
| 690841 | $TC_2$ | 5.4 | 15.33 | 4.57 | 37.02 | 2.03 | 2.50 | 1.36 |
| ------ | $CC_2$, $TC_2$<br>CC of $CT_2$ | 13.8 | 15.58 | 11.65 | 37.89 | 5.18 | 6.52 | 1.40 |

## TABLE 24A

## AGGLOMERATE FLOTATION TEST NO. 123 DOLOMITE MODIFIED WET COLLECTED SLD

1. 2150 ml SLD slurry added to flotation cell, 6.35 ml FAS added, conditioned for 15 minutes.

2. Carbonated to pH 6.8 at 2400 RPM, 10 PPT emulsion added, floated 4 minutes, RC recleaned twice.

3. $CT_1$ recleaned with additional 2.5 PPT emulsion for 2 minutes.

4. RT recleaned twice after recarbonation to pH 6.8, additional 5.0 PPT emulsion added before float.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| ------ | Feed | 153.8 | ----- | ----- | 19.60 | ----- | ----- | ---- |
| ------ | RC | 31.3 | 11.25 | 27.78 | 22.19 | 18.06 | 20.43 | 1.13 |
| ------ | $CC_1$ | 16.0 | 11.57 | 14.15 | 23.14 | 9.20 | 10.85 | 1.13 |
| 690844 | $CC_2$ | 6.2 | 12.20 | 5.44 | 24.20 | 3.53 | 4.36 | 1.23 |
| 690846 | $CT_2$ | 9.8 | 11.09 | 8.71 | 22.49 | 5.66 | 1.49 | 1.14 |
| ------ | $CT_1$ | 15.3 | 10.92 | 13.63 | 21.21 | 8.86 | 9.58 | 1.03 |
| 690845 | CC of $CT_1$ | 3.4 | 11.54 | 3.01 | 24.07 | 1.95 | 2.40 | 1.22 |
| 690847 | CT of $CT_1$ | 11.9 | 10.74 | 10.62 | 20.39 | 6.90 | 7.18 | 1.04 |
| ------ | RT | 122.5 | 10.45 | 109.70 | 18.61 | 71.32 | 67.71 | 0.95 |
| 690849 | $TT_1$ | 89.2 | 10.04 | 80.24 | 16.98 | 52.17 | 45.19 | 0.86 |
| ------ | $TC_1$ | 33.3 | 11.54 | 29.46 | 23.05 | 19.15 | 22.52 | 1.17 |
| 690850 | $TT_2$ | 15.0 | 11.02 | 13.35 | 20.82 | 8.68 | 9.22 | 1.06 |
| 690848 | $TC_2$ | 18.3 | 11.97 | 16.11 | 24.90 | 10.47 | 13.30 | 1.27 |
| ------ | $CC_2$,$TC_2$<br>CC of $CT_2$ | 27.9 | 11.98 | 24.56 | 24.64 | 15.96 | 20.07 | 1.26 |

## TABLE 25A

## EMULSION FLOTATION TEST NO. 124 LIMESTONE MODIFIED FLYASH KPL

1. KPL Slurry added to flotation cell, 4 PPT of 10,000 PPM $Na_2S$ added.

2. 1 PPT Duomac T added, 1 drop A65 Frother added.

3. Floated 3 minutes.

4. Recleaned concentrate for 3 minutes with additional 1 PPT Duomac T and 1 drop A65 Frother.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 700071 | $RC_1$ | 2.9 | 12.45 | 2.539 | 47.68 | 11.38 | 18.43 | ---- |
| 700072 | $RC_2$ | 14.0 | 6.18 | 13.135 | 32.81 | 58.90 | 65.65 | ---- |
| 700073 | RT | 7.3 | 10.15 | 6.56 | 28.35 | 29.42 | 28.33 | ---- |

## TABLE 26A

### AGGLOMERATE FLOTATION TEST NO. 125 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 1.0 PPT FAS added, then 400 grams PID

2. Preconditioned for 1.0 hour at 1700 RPM

3. Carbonated to 6.1 at 2400 RPM.

4. 5.0 PPT Emulsion added, conditioned for 3 1/2 min., rougher separation 4 min., held at 1700 RPM.

5. Recleaned RC for 2 min., remixed tail cleaner products with RT, repeated step 4 three times.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 700120 | $CC_1$ | 34.0 | 30.18 | 23.74 | 48.75 | 5.93 | 9.71 | 1.64 |
| 700121 | $CC_2$ | 55.0 | 29.53 | 38.76 | 45.72 | 9.69 | 14.87 | 1.53 |
| 700122 | $CC_3$ | 49.5 | 27.63 | 35.82 | 42.82 | 8.95 | 12.87 | 1.44 |
| 700123 | $CC_4$ | 100.2 | 20.47 | 79.69 | 32.03 | 19.92 | 21.42 | 1.08 |
| 700124 | $CT_4$ | 73.2 | 13.06 | 63.64 | 20.04 | 15.91 | 10.70 | 0.67 |
| 700125 | RT | 13.30 | 8.82 | 121.27 | 14.13 | 30.31 | 14.38 | 0.47 |
| ------ | $CC_1$, $CC_2$, $CC_3$, $CC_4$ | 238.2 | 25.27 | 178.01 | 39.41 | 44.50 | 58.87 | 1.32 |

## TABLE 27A

## AGGLOMERATE FLOTATION TEST NO. 126 LIMESTONE MODIFIED FLYASH PID

1. 2000 ml $H_2O$ added to flotation cell, 1.0 PPT FAS added, then 400 grams PID.

2. Preconditioned for 1.0 hour at 1700 RPM.

3. Carbonated to 6.1 at 2400 RPM.

4. 10 PPT Emulsion added, conditioned for 3 1/2 min., rougher separation 4 min., held at 1700 RPM.

5. Recleaned RC for 2 min., remixed cleaner tail products with RT, add 5.0 PPT emulsion and repeated step 4 two times.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 700140 | $CC_1$ | 27.2 | 26.77 | 19.92 | 44.19 | 4.98 | 7.38 | 1.48 |
| 700141 | $CC_2$ | 21.0 | 27.31 | 15.26 | 43.31 | 3.81 | 5.54 | 1.45 |
| 700142 | $CC_3$ | 23.4 | 28.57 | 16.71 | 45.94 | 4.17 | 6.44 | 1.54 |
| 700143 | $CT_3$ | 50.2 | 19.79 | 40.27 | 30.71 | 10.06 | 10.37 | 1.01 |
| 700144 | RT | 319.3 | 15.86 | 268.66 | 22.05 | 67.16 | 49.71 | 0.74 |
| ------ | $CC_1$, $CC_2$, $CC_3$ | 71.6 | 27.35 | 51.89 | 44.49 | 12.97 | 19.37 | 1.49 |

## TABLE 28A

## AGGLOMERATE FLOTATION TEST NO. 127 LIMESTONE MODIFIED FLYASH PID

1. 400 grams of PID flyash and 100 grams of $H_2O$ were attritionally scrubbed for three hours at 2000 RPM.

2. Removed to flotation cell, 1900 ml $H_2O$ added, 1 PPT FAS modifier added and conditioned for 1 hr.

3. Carbonated to pH 6.4, emulsion added at rate of 10 PPT, conditioned for 2 hrs.

4. Floated with $CO_2$ for 6 min.

5. Concentrate reconditioned for 45 minutes after addition of 5 PPT emulsion.

6. Recleaned with air for 5 min.

| Log Number | Fraction | Wt. Rec. Gms. | L.O.I. | Ignited Residue Gms. | Percent CaO | Percent Floated | Percent CaO Rec. | Ratio of Enrichment |
|---|---|---|---|---|---|---|---|---|
| FEED | | 400.0 | 1.03 | 395.88 | 29.79 | | | |
| 700145 | CC | 89.2 | 26.13 | 65.89 | 36.40 | 16.47 | 20.12 | 1.22 |
| 700146 | CT | 189.3 | 16.70 | 157.69 | 24.94 | 39.42 | 33.00 | 0.84 |
| ------ | RC | 278.5 | 19.72 | 223.58 | 28.31 | 55.89 | 53.13 | 0.95 |
| 700147 | RT | 138.5 | 16.00 | 116.34 | 24.68 | 29.08 | 24.09 | 0.33 |

# APPENDIX B

## ZETA POTENTIAL DATA

FIGURE 1B

THE CHANGE IN ZETA POTENTIAL AND SPECIFIC CONDUCTANCE WITH pH OF CONCENTRATED AND DILUTE SLURRIES OF MODIFIED FLYASH SAMPLE PID (St. Clair, Mich.)
(Sample Filtered)

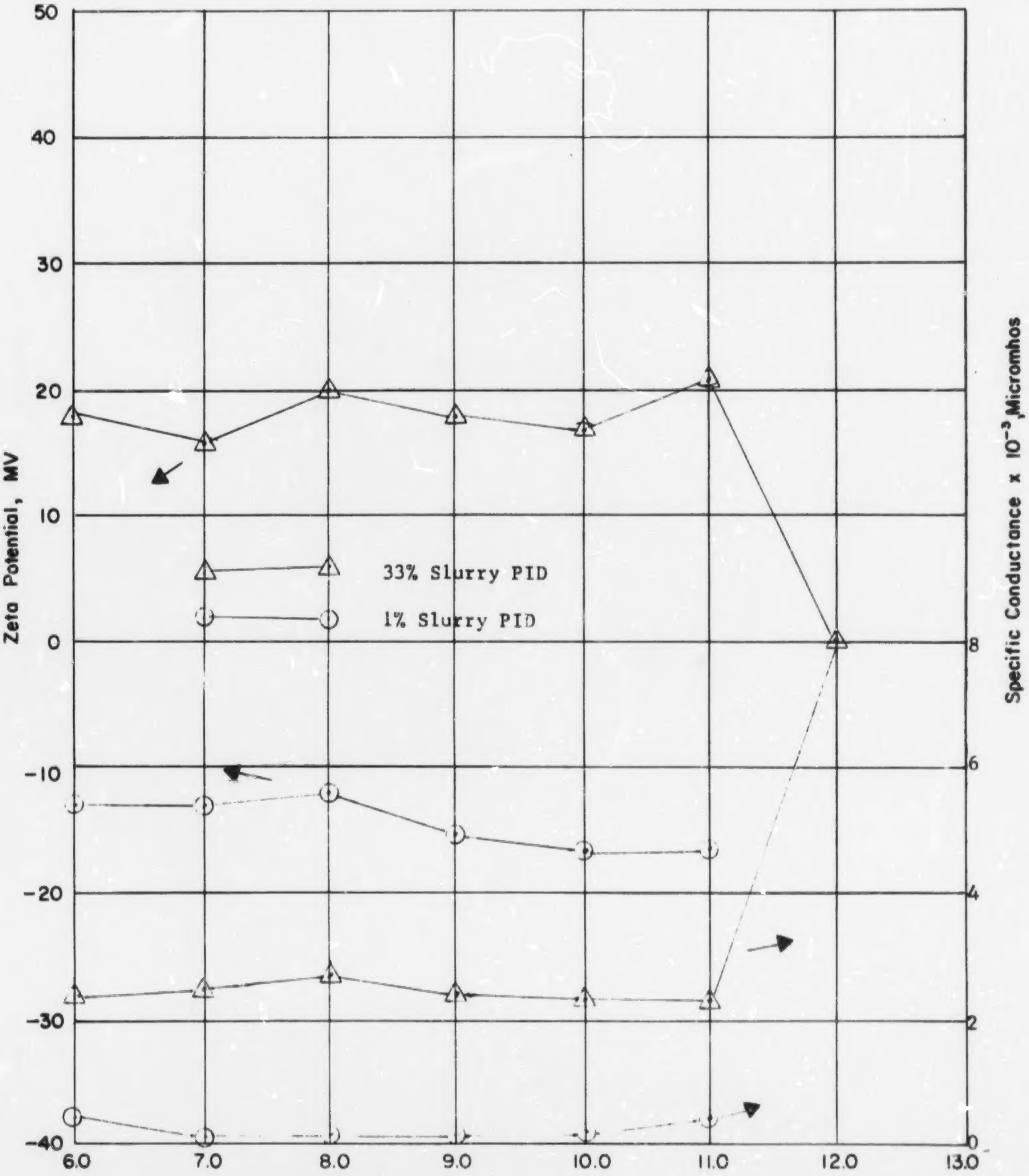


FIGURE 2B

THE EFFECT OF pH ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF 33 PERCENT SLURRIES OF MODIFIED FLYASH PID AND THE COAL ASH CONSTITUENTS OF PID (UNMODIFIED FLYASH DE1) IN A LIQUOR CONTAINING THE SOLUBLE CONSTITUENTS OF PID

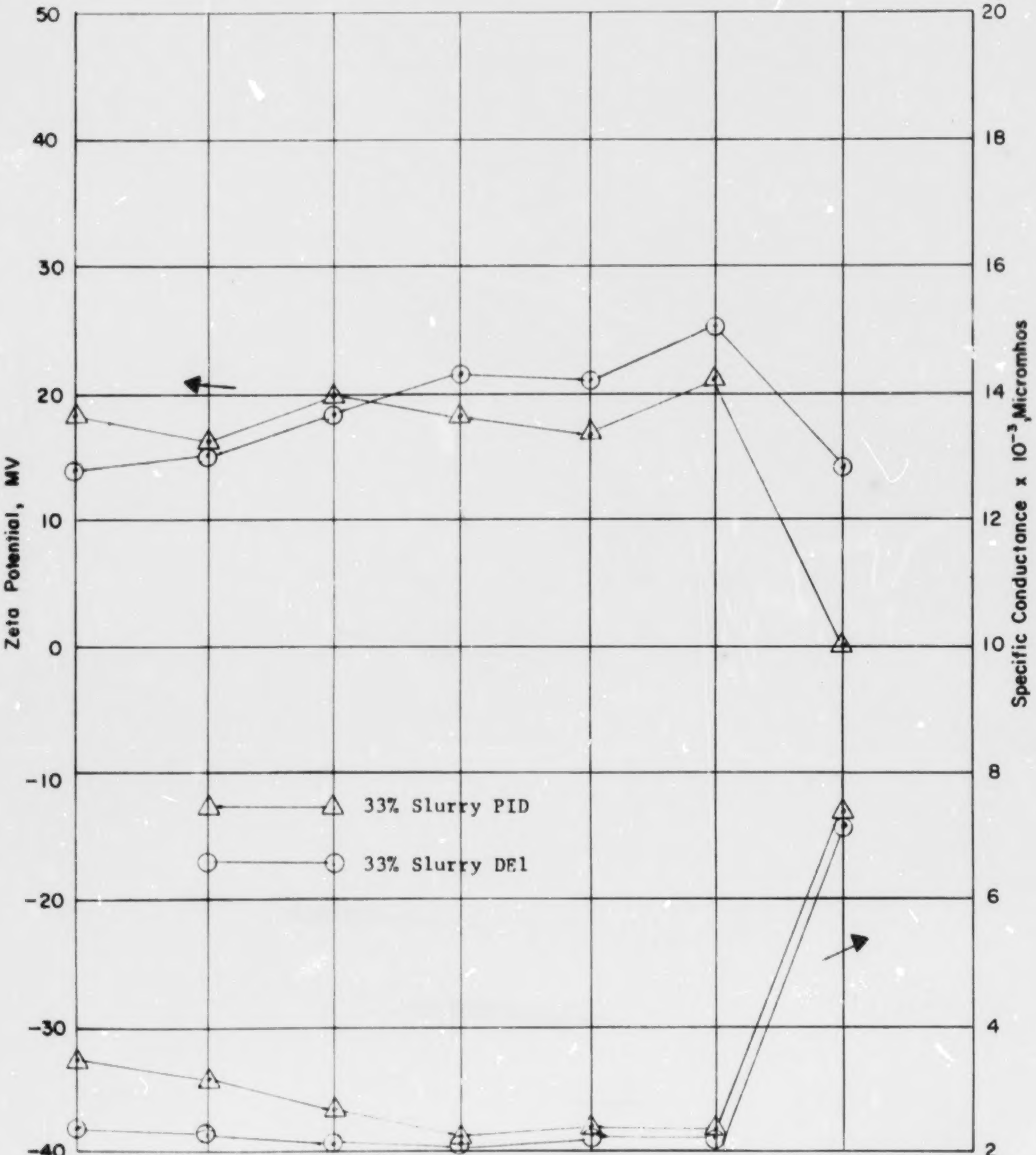


FIGURE 3B

THE CHANGE IN ZETA POTENTIAL AND SPECIFIC CONDUCTANCE WITH CHANGES IN THE pH OF CONCENTRATED AND DILUTE SLURRIES OF UNMODIFIED FLYASH SAMPLE DE1
(St. Clair, Mich.)

(Sample Filtered)

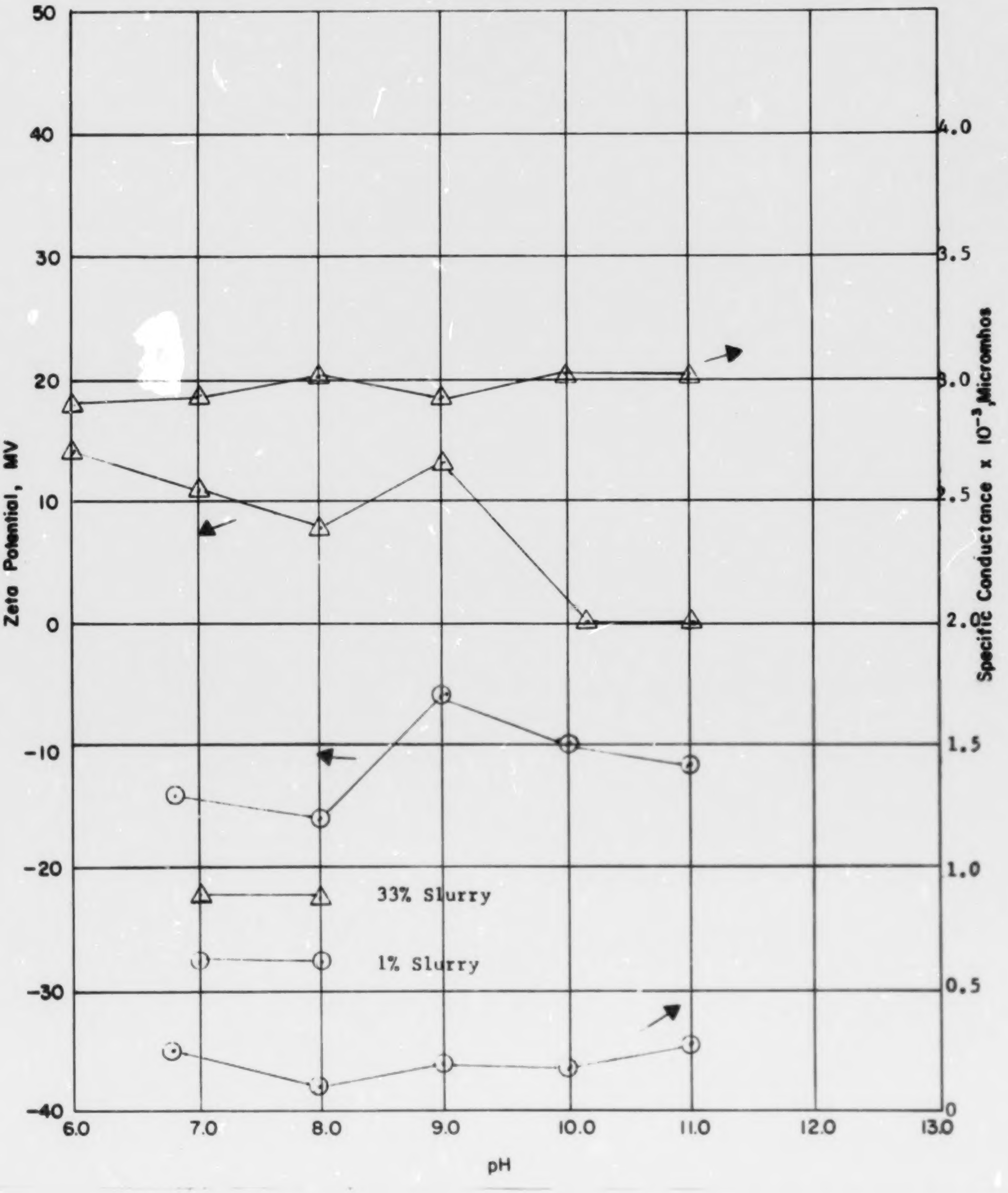


FIGURE 4B

### THE CHANGE IN ZETA POTENTIAL AND SPECIFIC CONDUCTANCE WITH CHANGES IN THE pH OF CONCENTRATED AND DILUTE SLURRIES OF LIMESTONE MODIFIED FLYASH SAMPLE PID
(St. Clair, Mich.)
(Sample Filtered)

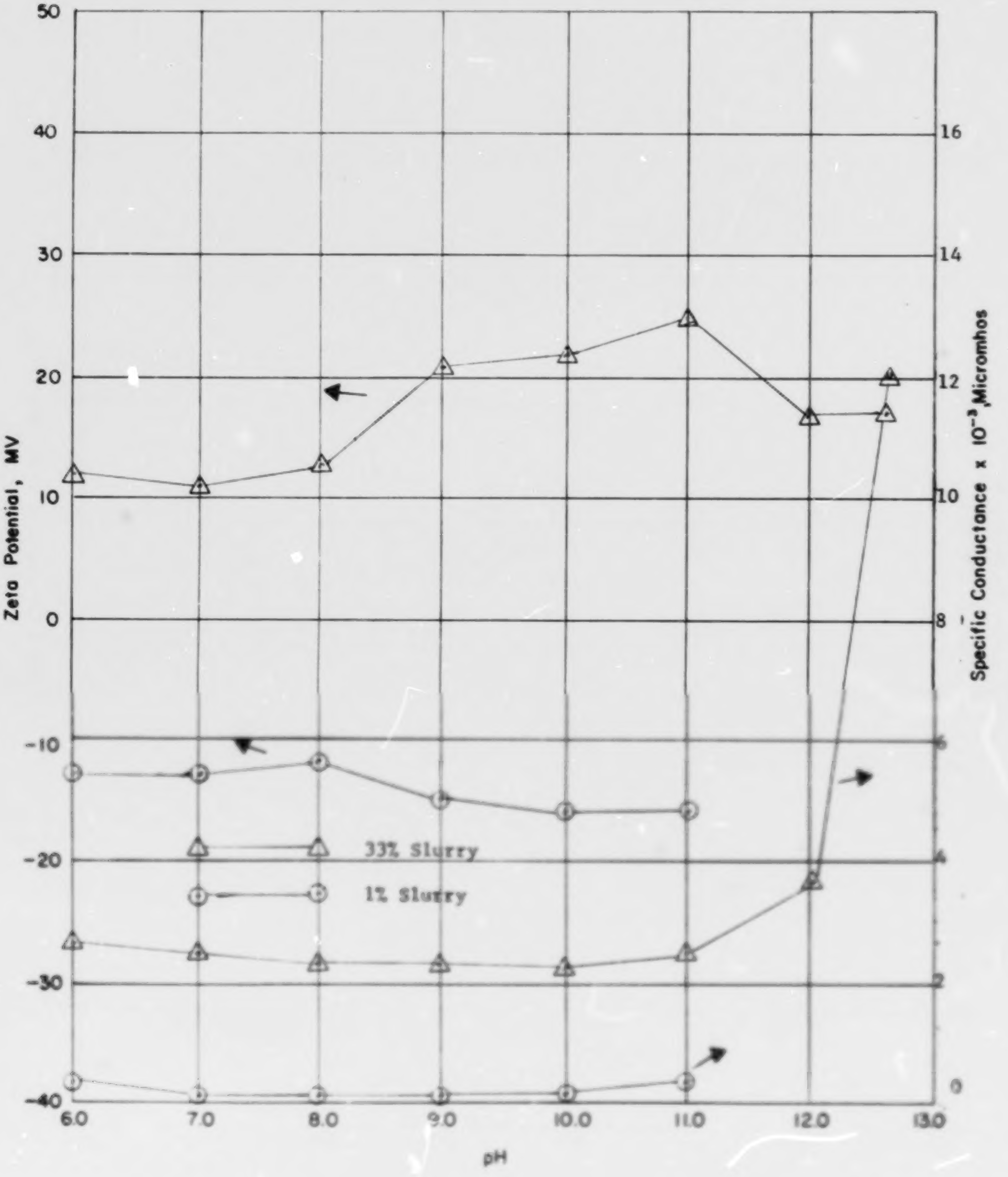


FIGURE 5B

THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE WITH CHANGES IN pH OF LIMESTONE MODIFIED FLYASH PID (St. Clair, Mich.), THE COAL ASH CONSTITUENTS OF PID AND THE LIME CONSTITUENTS OF PID IN LIQUORS CONTAINING THE SOLUBLE CONSTITUENTS OF PID

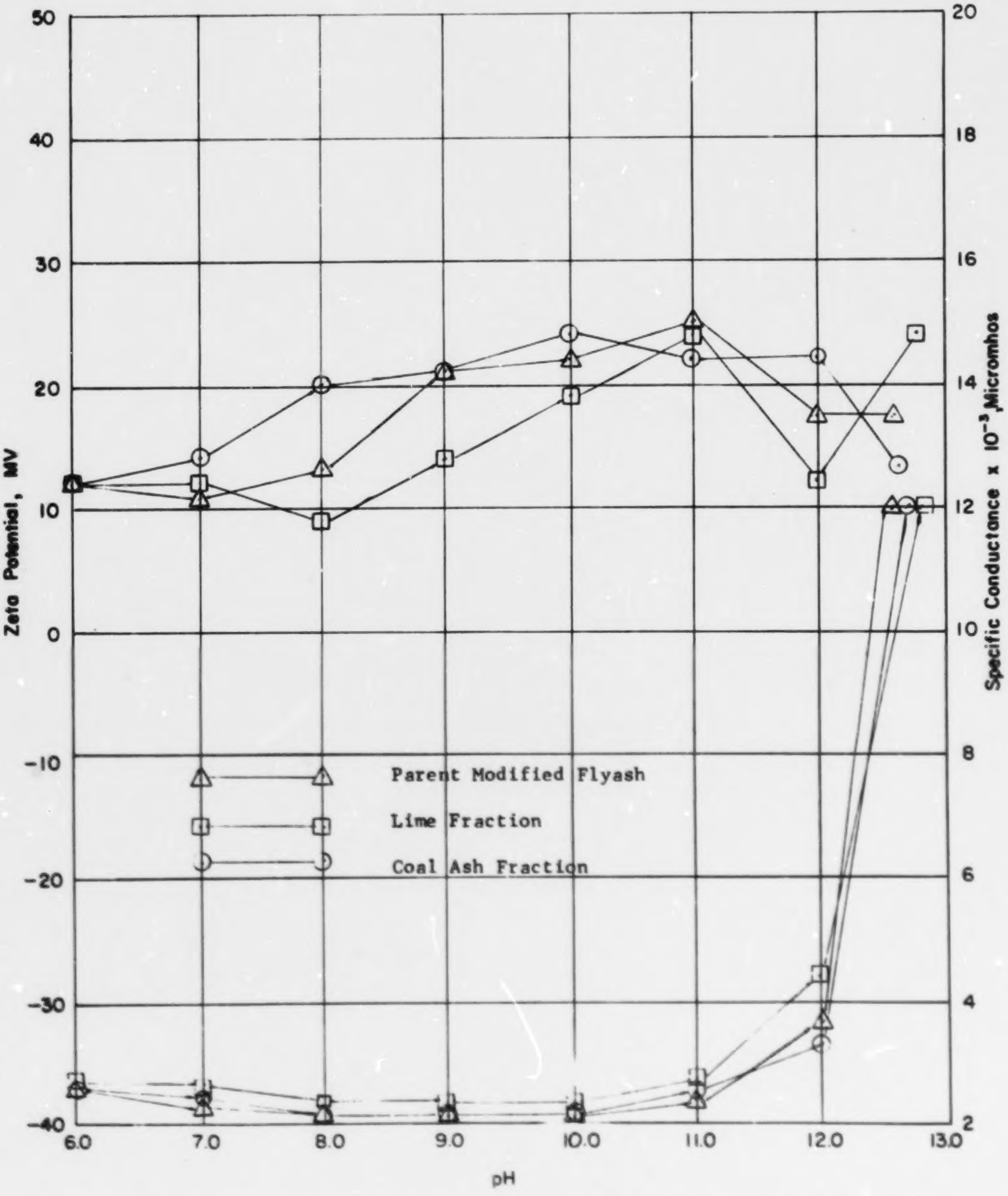


FIGURE 6B

THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE WITH CHANGES IN pH OF LIMESTONE MODIFIED FLYASH D1D2 (TVA), THE COAL ASH CONSTITUENTS OF D1D2 AND THE LIME CONSTITUENTS OF D1D2 IN LIQUORS CONTAINING THE SOLUBLE CONSTITUENTS OF D1D2

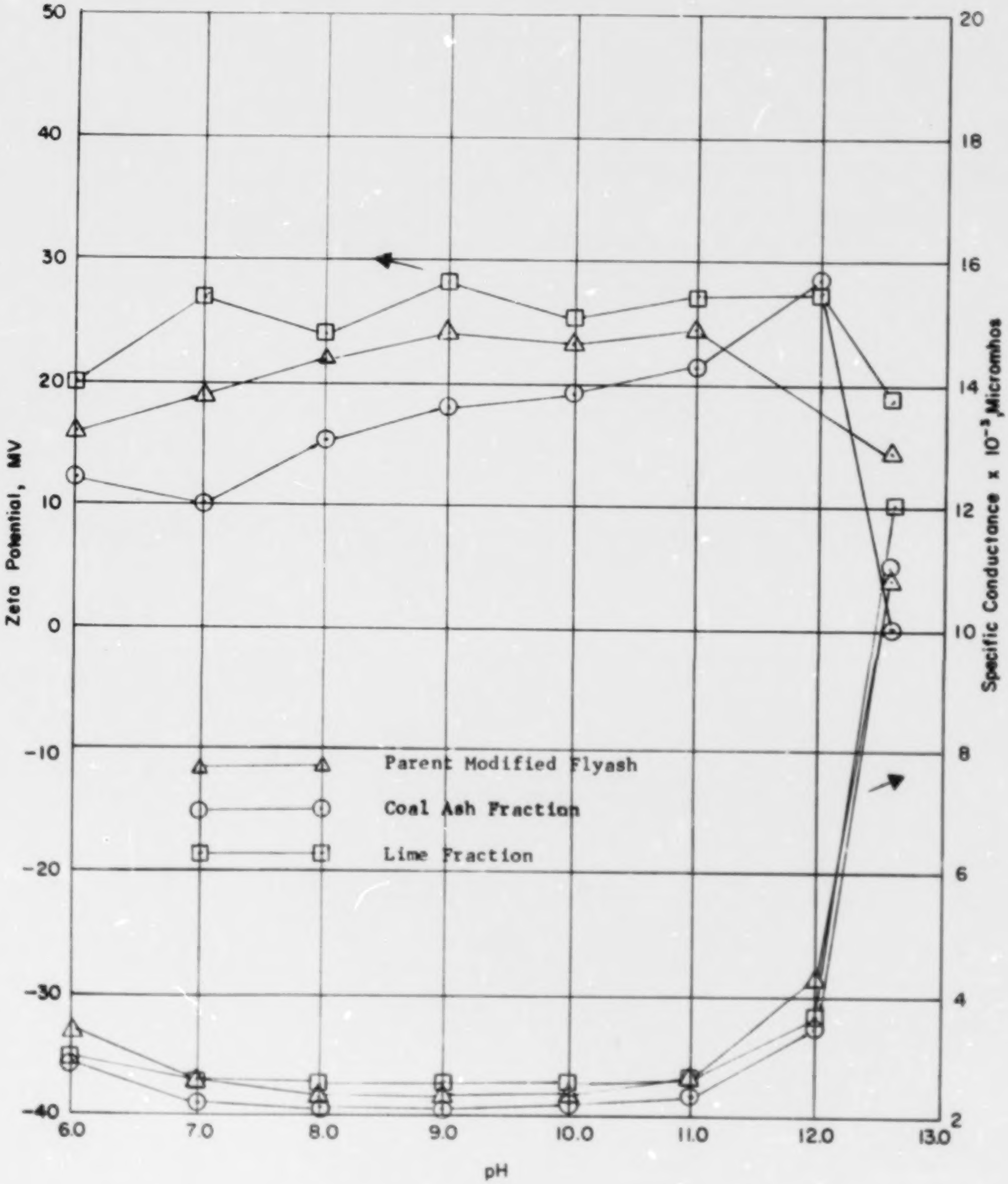


FIGURE 7B

THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE WITH CHANGES IN pH OF LIMESTONE MODIFIED FLYASH D1D3 (TVA), THE COAL ASH CONSTITUENTS OF D1D3 AND THE LIME CONSTITUENTS OF D1D3 IN LIQUORS CONTAINING THE SOLUBLE CONSTITUENTS OF D1D3

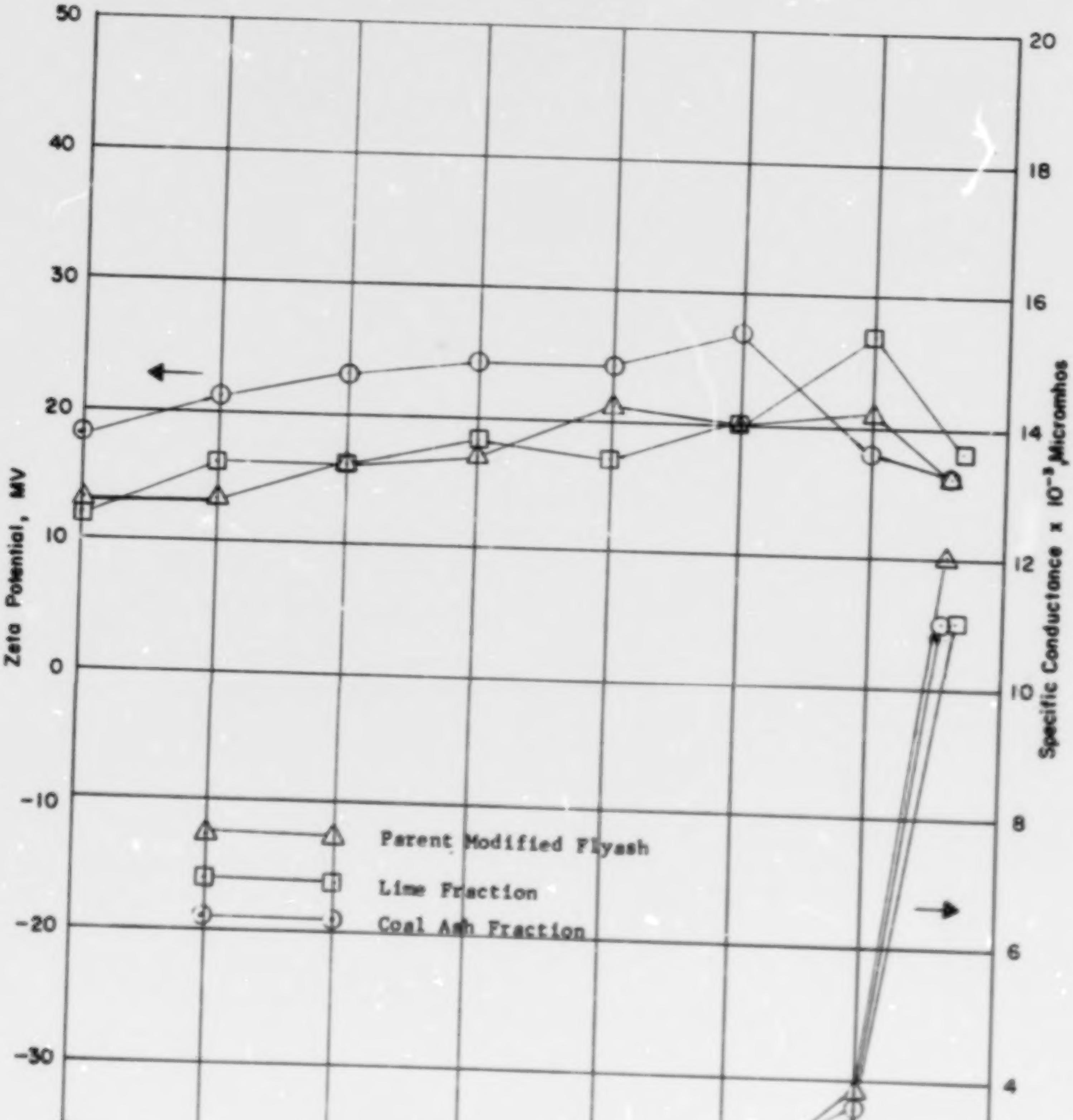


FIGURE 8B

THE EFFECT OF DILUTION TO OBTAIN THE TRUE VALUES FOR
THE ZETA POTENTIAL, SPECIFIC CONDUCTANCE AND pH OF 33
PERCENT SLURRIES OF MODIFIED FLYASH SAMPLE PID
(St. Clair, Mich.)

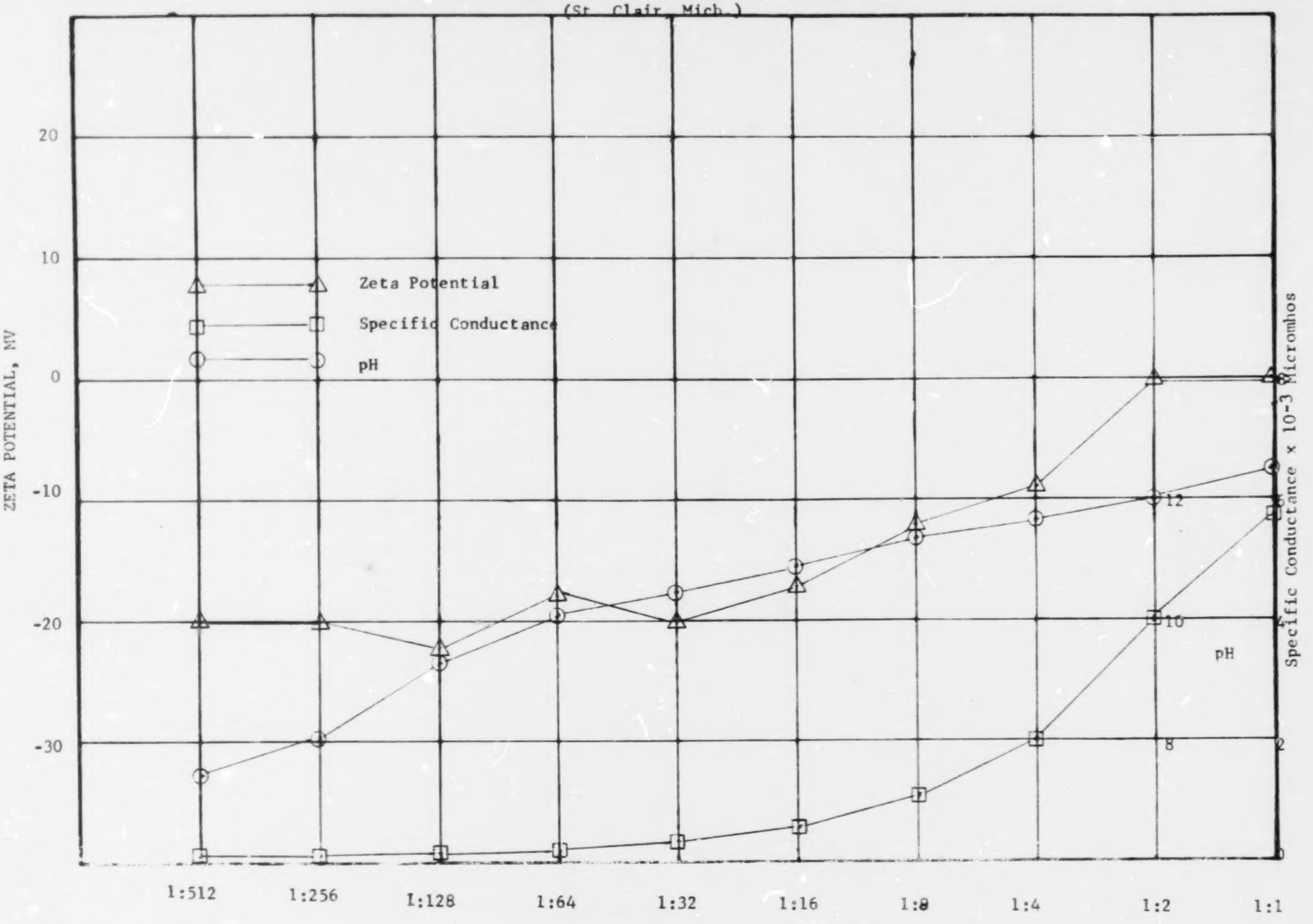


FIGURE 9B

THE EFFECT OF DILUTION TO OBTAIN THE TRUE VALUES FOR
THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF
33 PERCENT SLURRIES OF MODIFIED FLYASH SAMPLE PID
(St. Clair, Mich.)
at pH 6

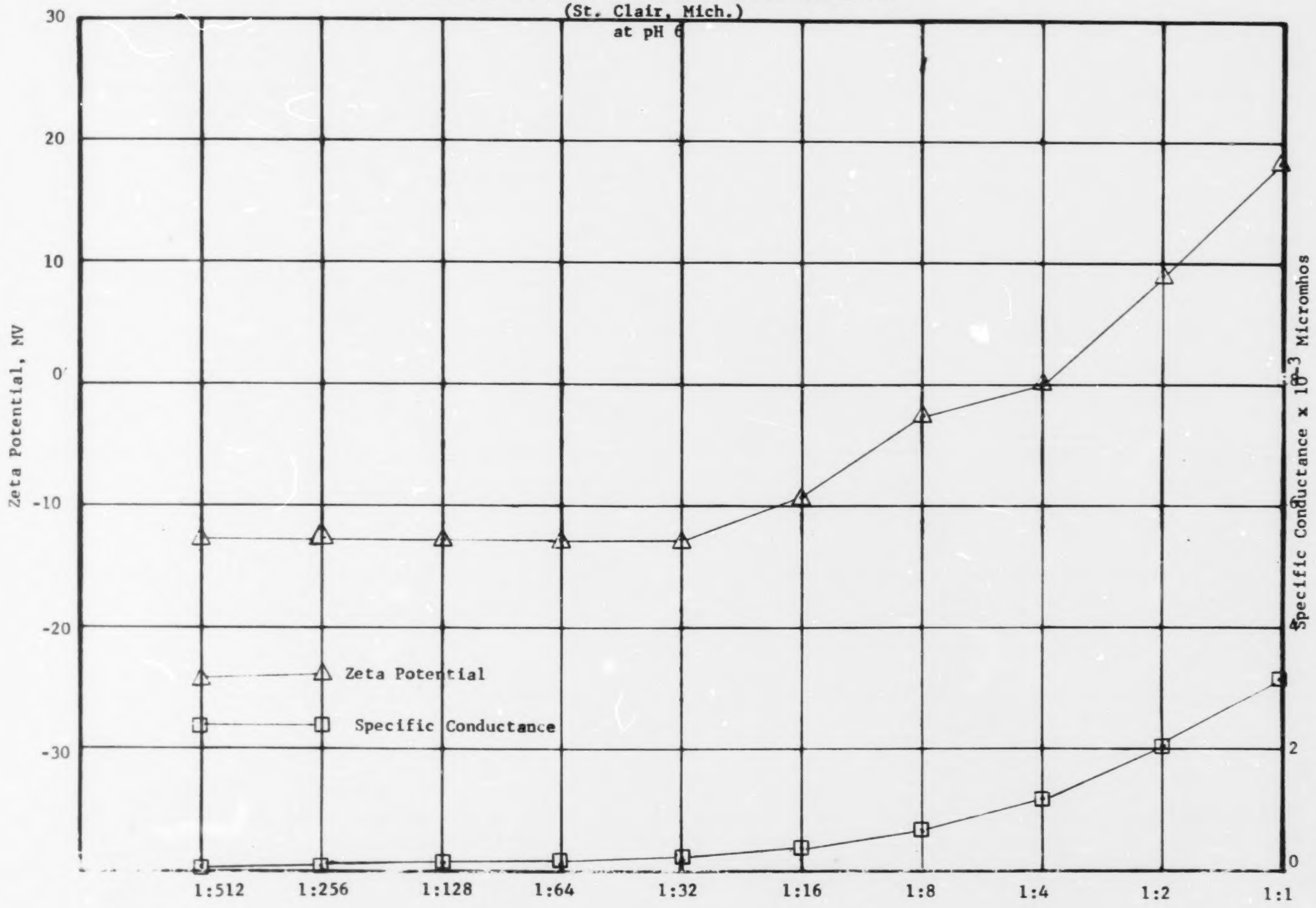


FIGURE 10B

THE EFFECT OF DILUTION TO OBTAIN THE TRUE VALUES FOR
THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF
33 PERCENT SLURRIES OF MODIFIED FLYASH SAMPLE PID
(St. Clair, Mich.)
at pH 7

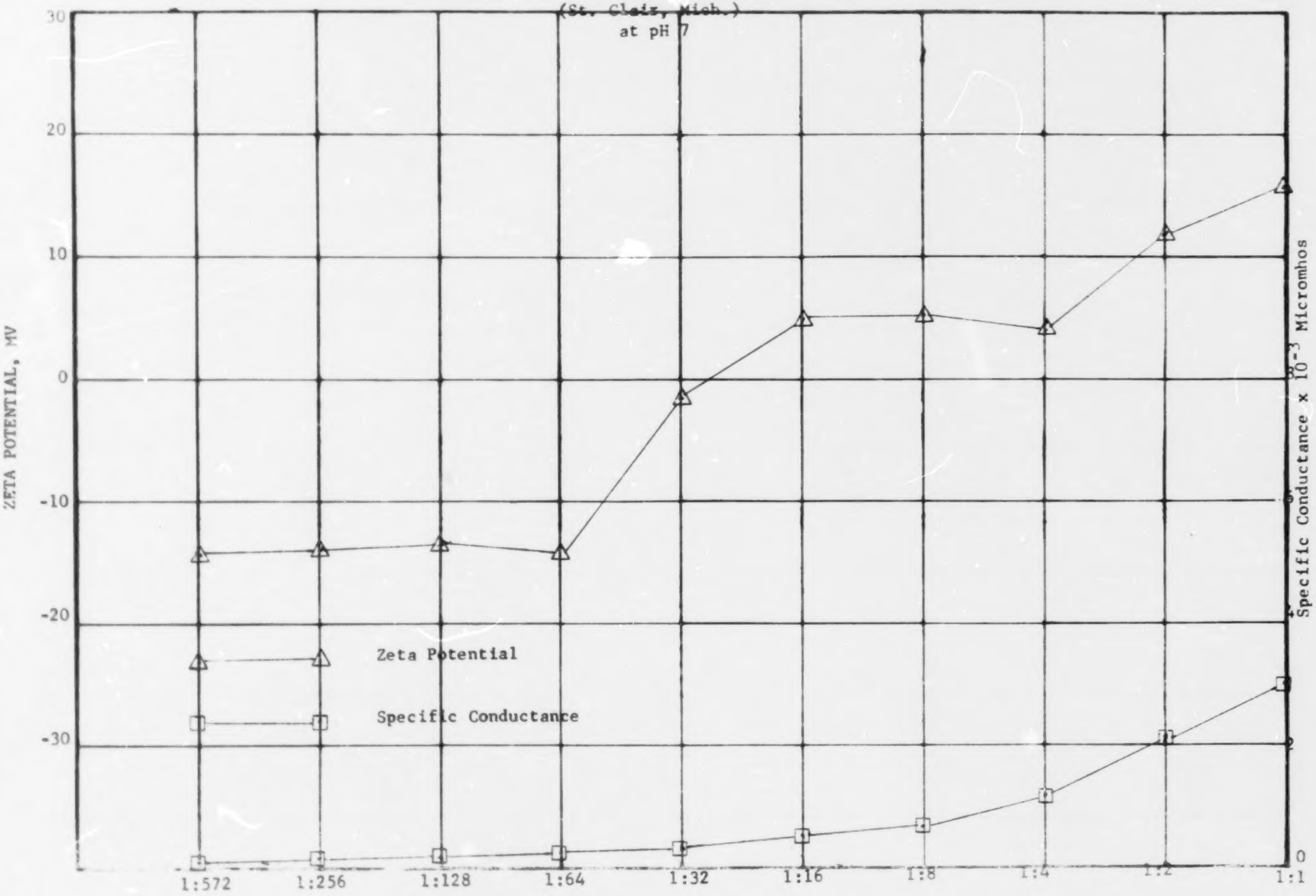


FIGURE 11B

THE EFFECT OF DILUTION TO OBTAIN THE TRUE VALUES FOR
THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF
33 PERCENT SLURRIES OF MODIFIED FLYASH SAMPLE PID
(St. Clair, Mich.)
at pH 8

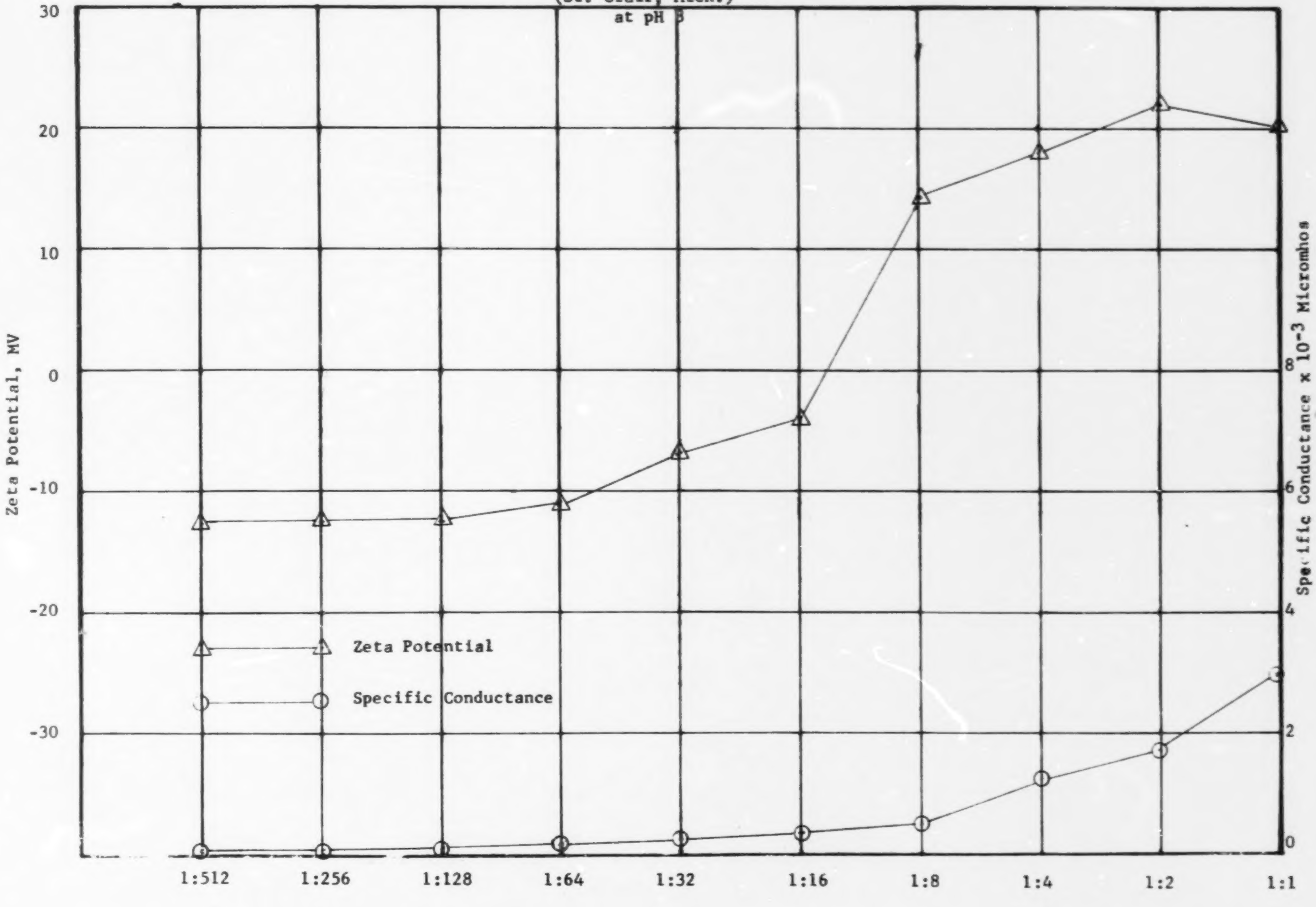


FIGURE 12B

THE EFFECT OF DILUTION TO OBTAIN THE TRUE VALUES FOR
THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF
33 PERCENT SLURRIES OF MODIFIED FLYASH SAMPLE PID
(St. Clair, Mich.)
at pH 9

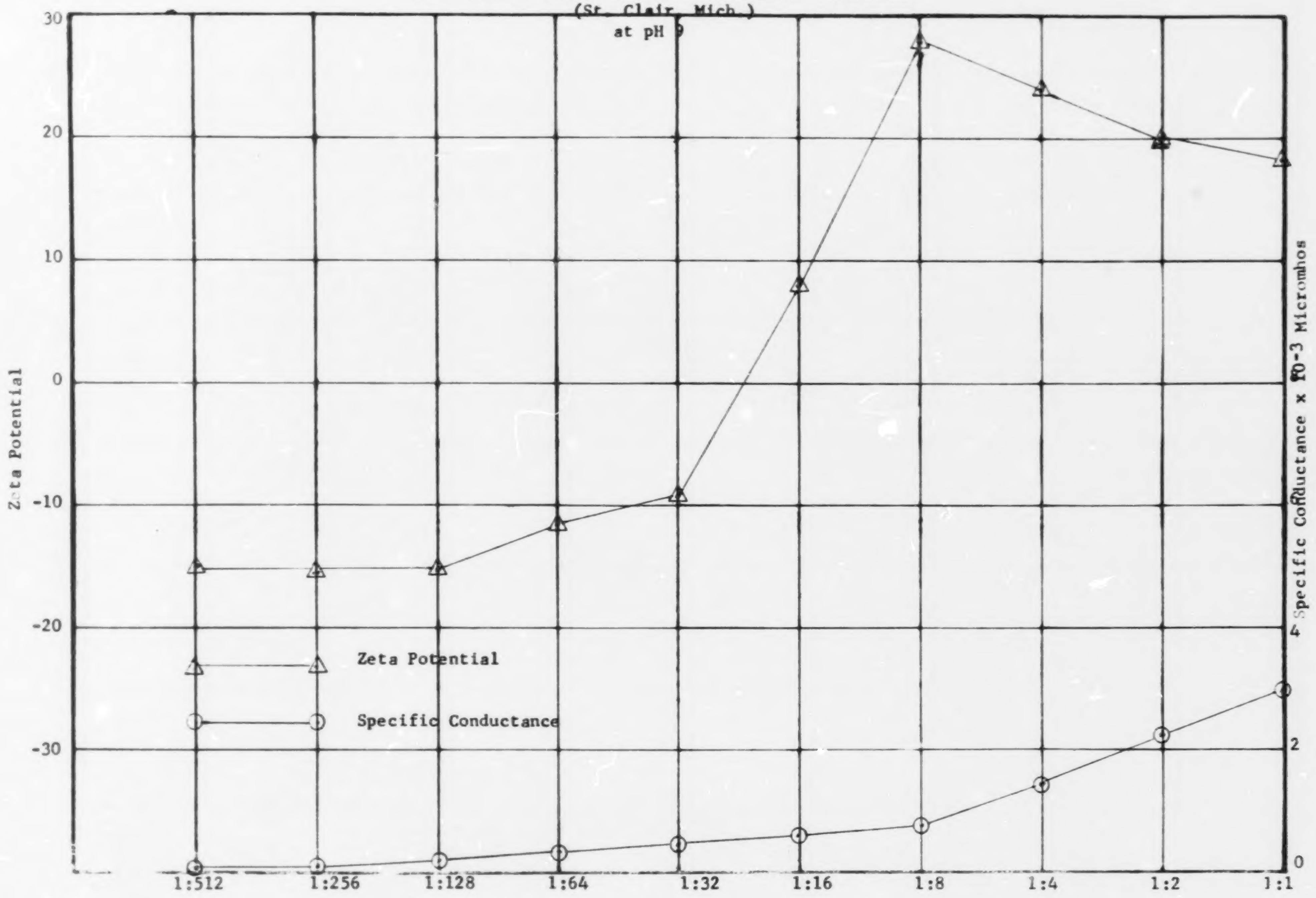


FIGURE 13B

THE EFFECT OF DILUTION TO OBTAIN THE TRUE VALUES FOR THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF 33 PERCENT SLURRIES OF MODIFIED FLYASH SAMPLE PID (St. Clair, Mich.) at pH 10

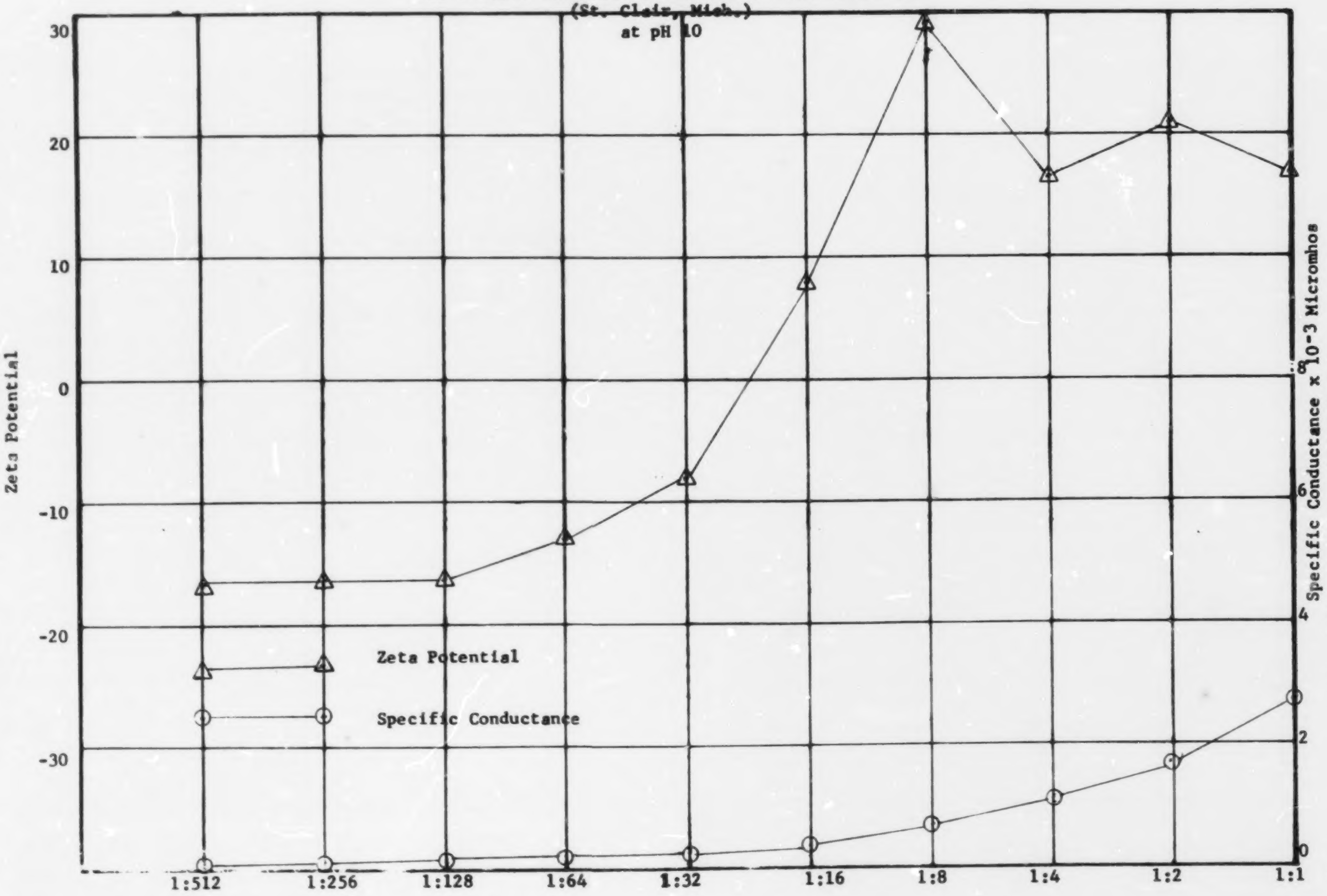


FIGURE 14B
THE EFFECT OF DILUTION TO OBTAIN THE TRUE VALUES FOR THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF 33 PERCENT SLURRIES OF MODIFIED FLYASH SAMPLE PID
(St. Clair, Mich.)
at pH 11

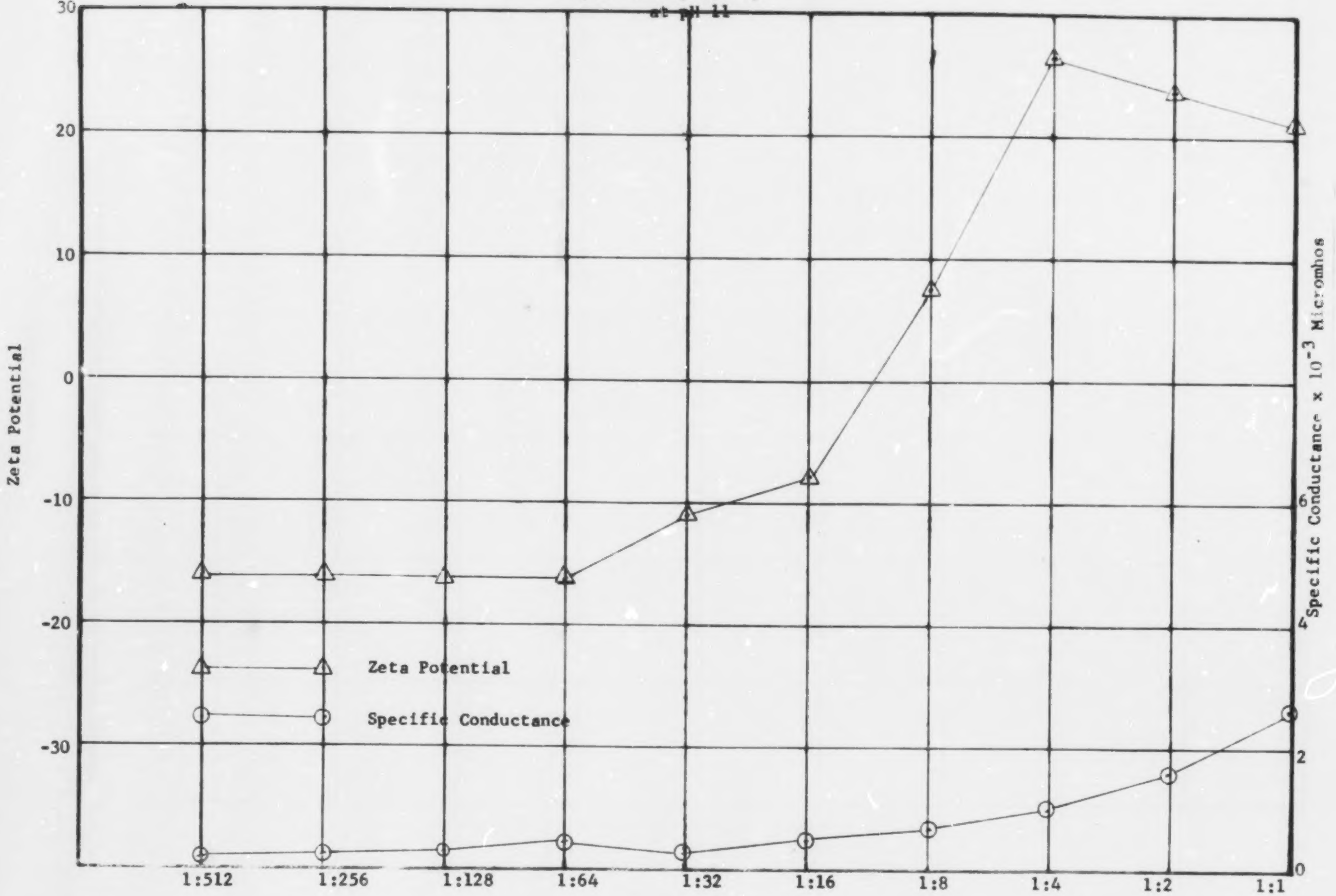


FIGURE 15B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 4 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM POTASSIUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

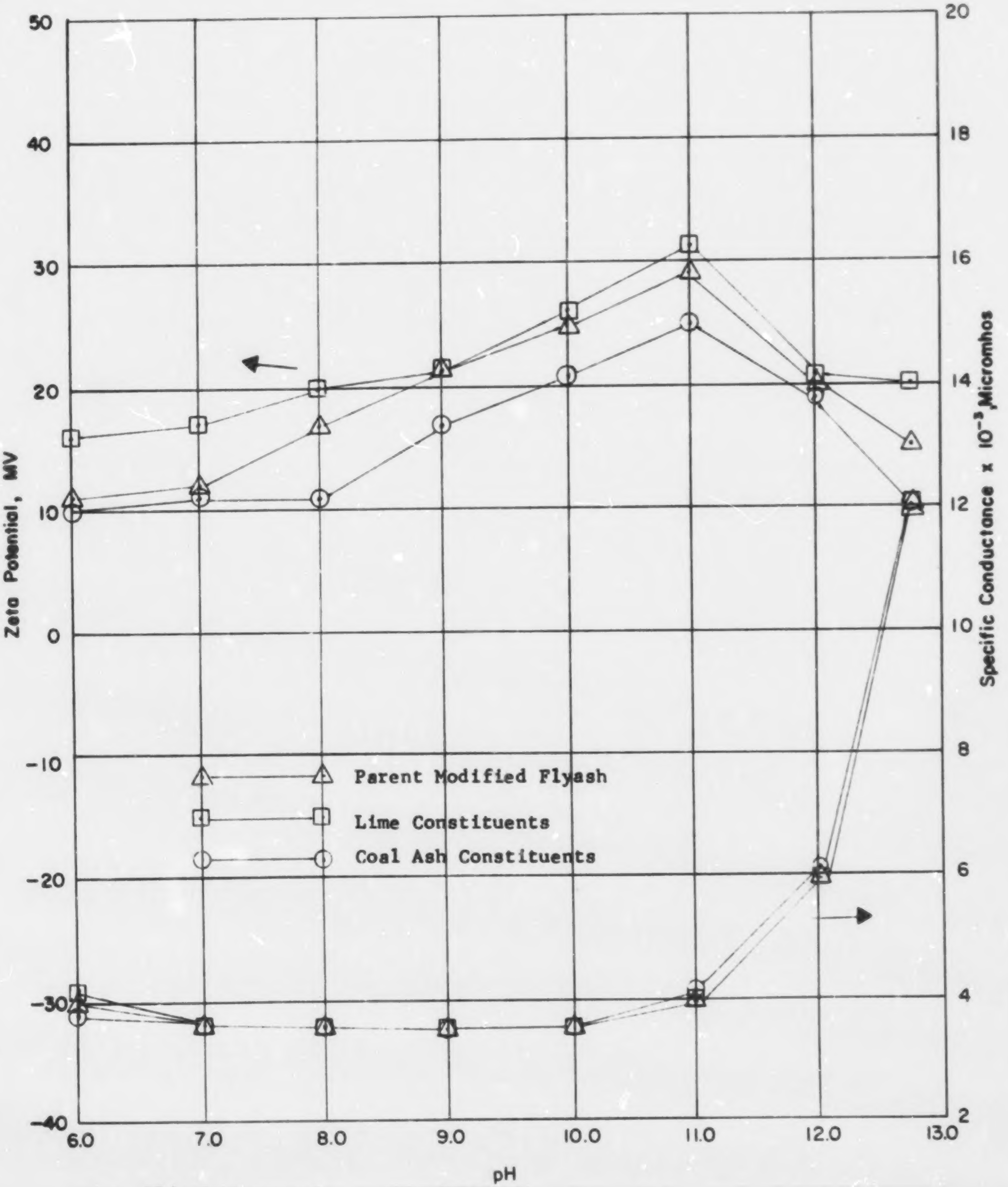


FIGURE 16B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 2 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM POTASSIUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

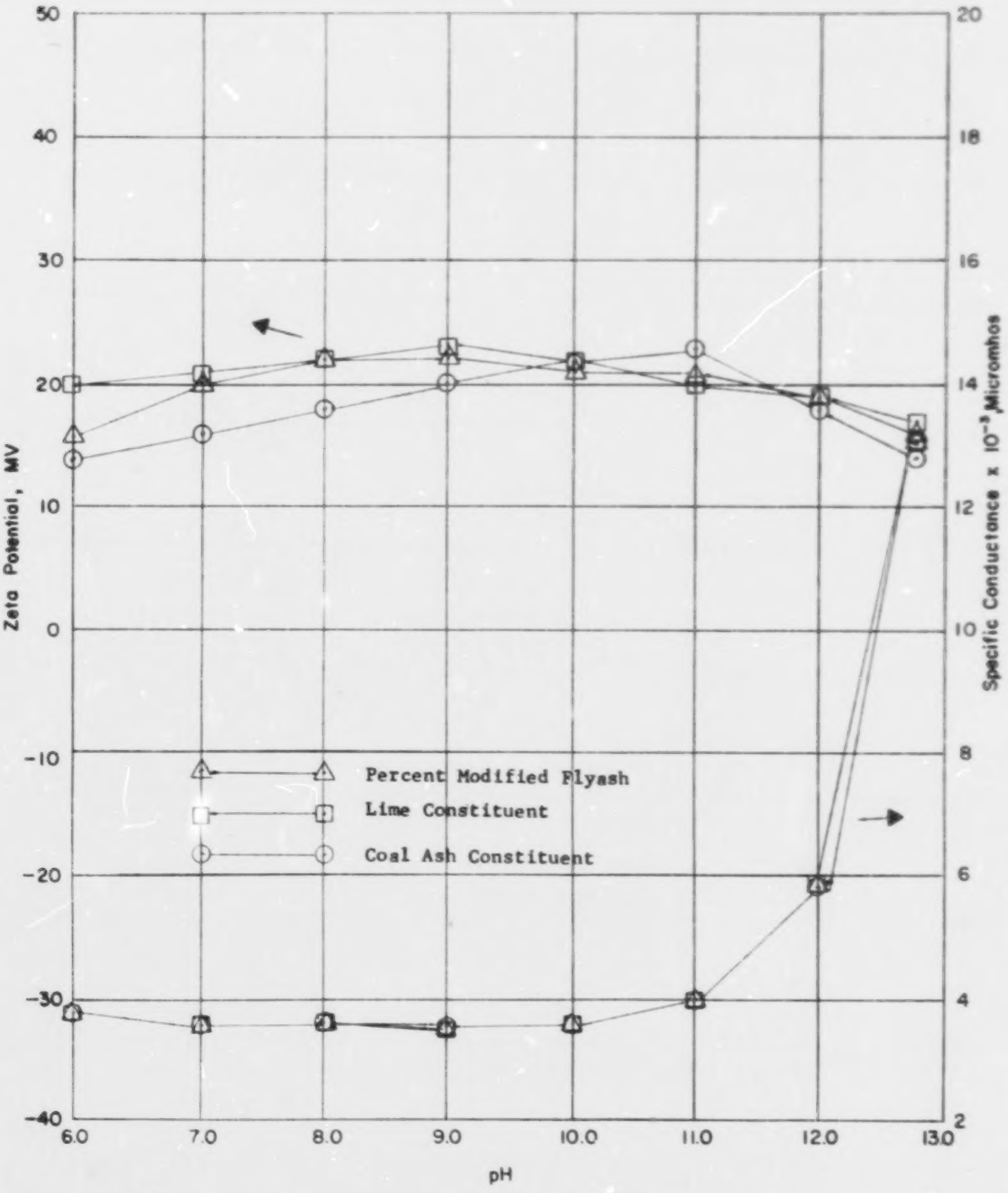


FIGURE 17B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1 POUND PER TON OF TRIVALENT ALUMINUM AS ALUMINUM POTASSIUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

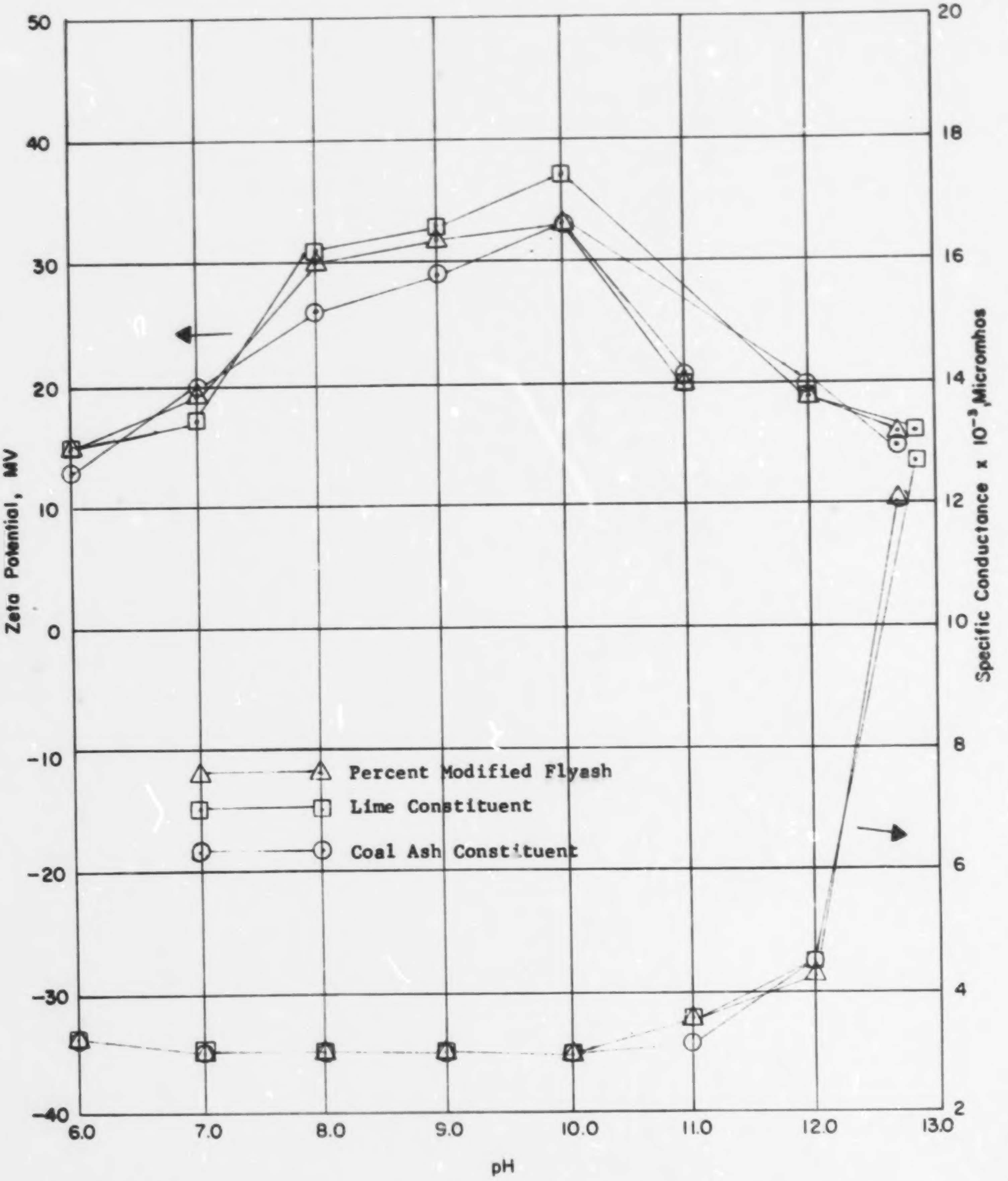


FIGURE 18B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.6 POUND PER TON OF TRIVALENT ALUMINUM AS ALUMINUM POTASSIUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

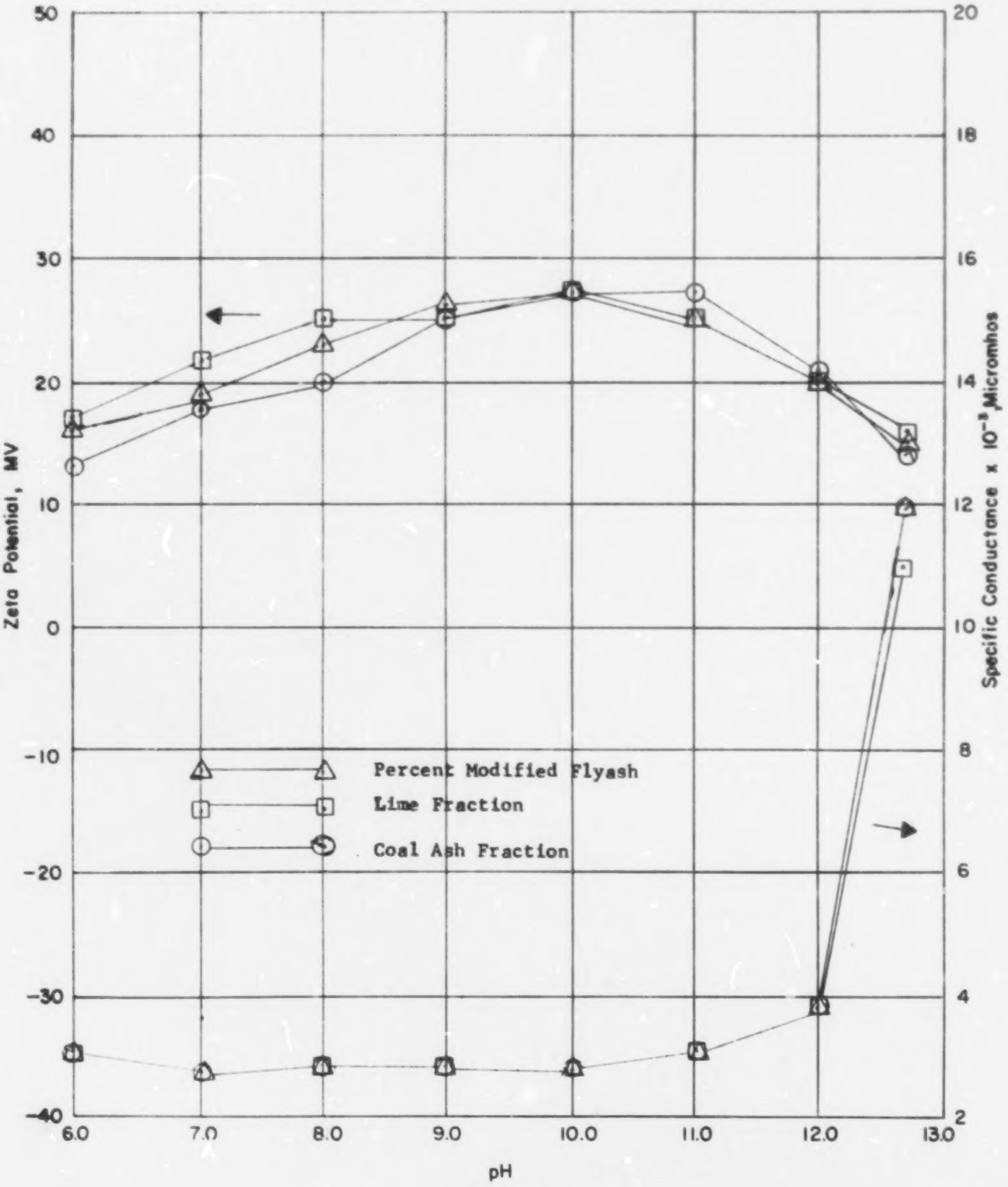


FIGURE 19B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.2 POUND PER TON OF TRIVALENT ALUMINUM AS ALUMINUM POTASSIUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

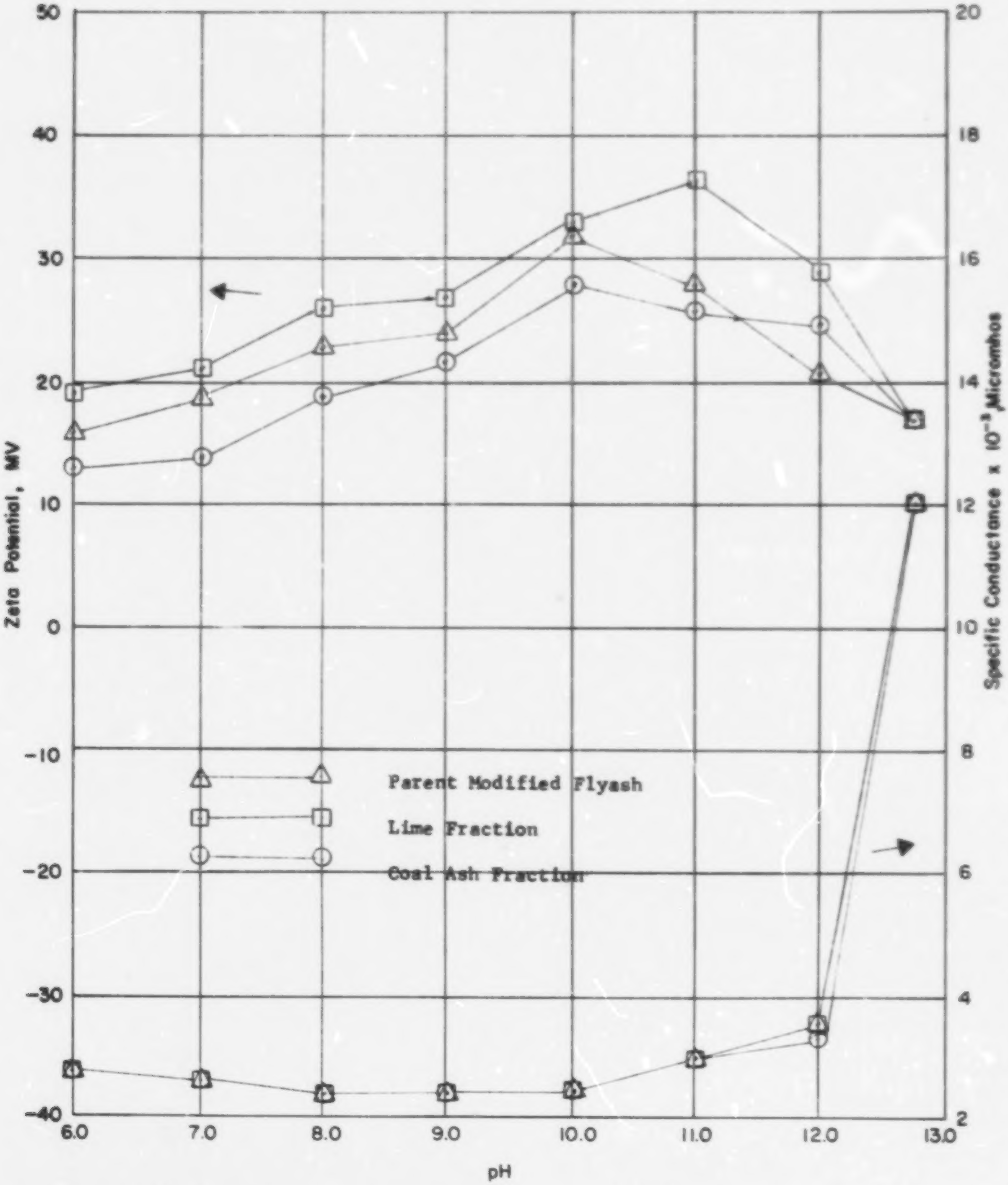


FIGURE 20B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 4 POUNDS PER TON OF DIVALENT SULFUR AS SODIUM SULFIDE TO A 33 PERCENT SLURRY CONCENTRATION

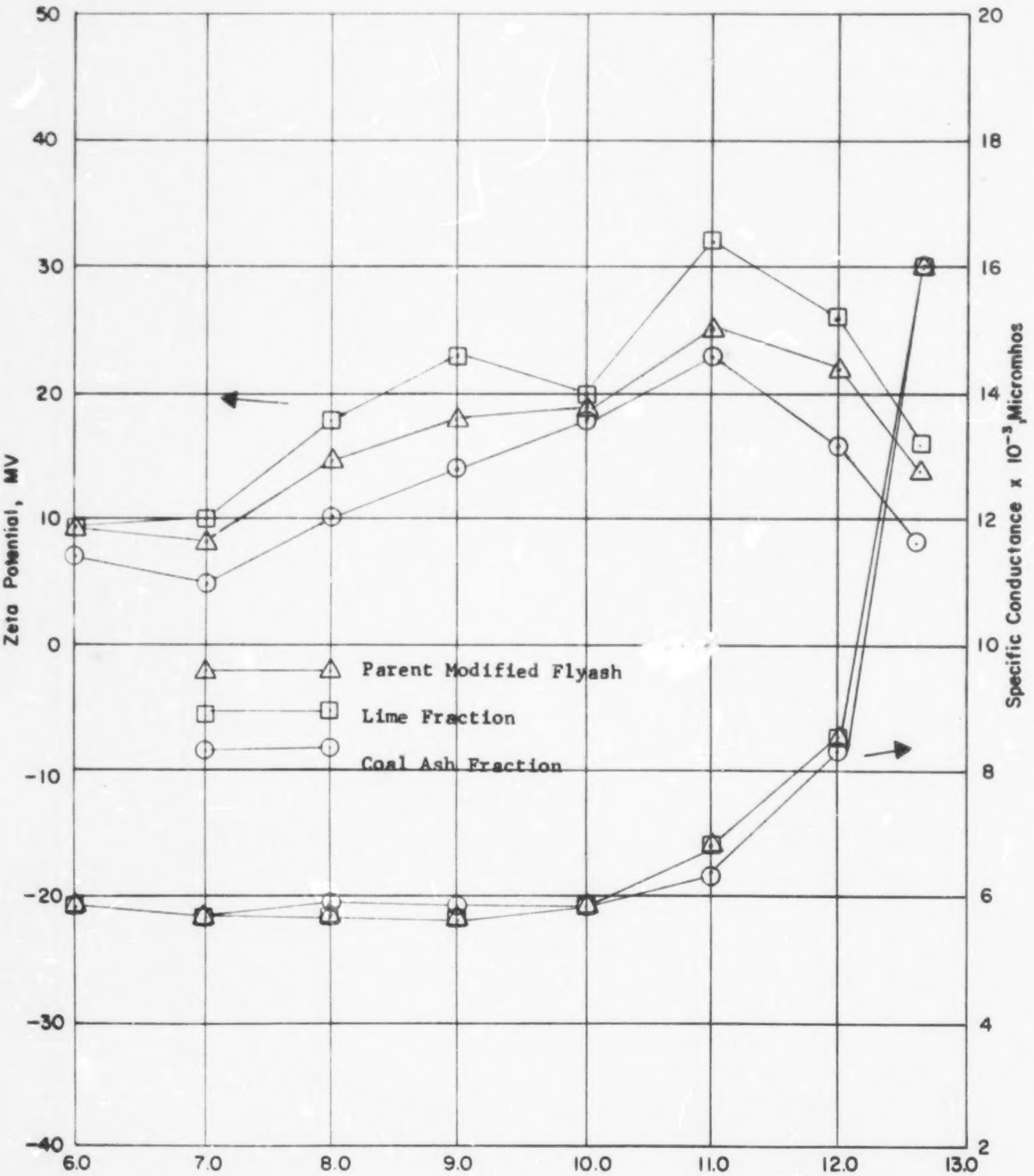


FIGURE 21B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 2 POUNDS PER TON OF DIVALENT SULFUR AS SODIUM SULFIDE TO A 33 PERCENT SLURRY CONCENTRATION

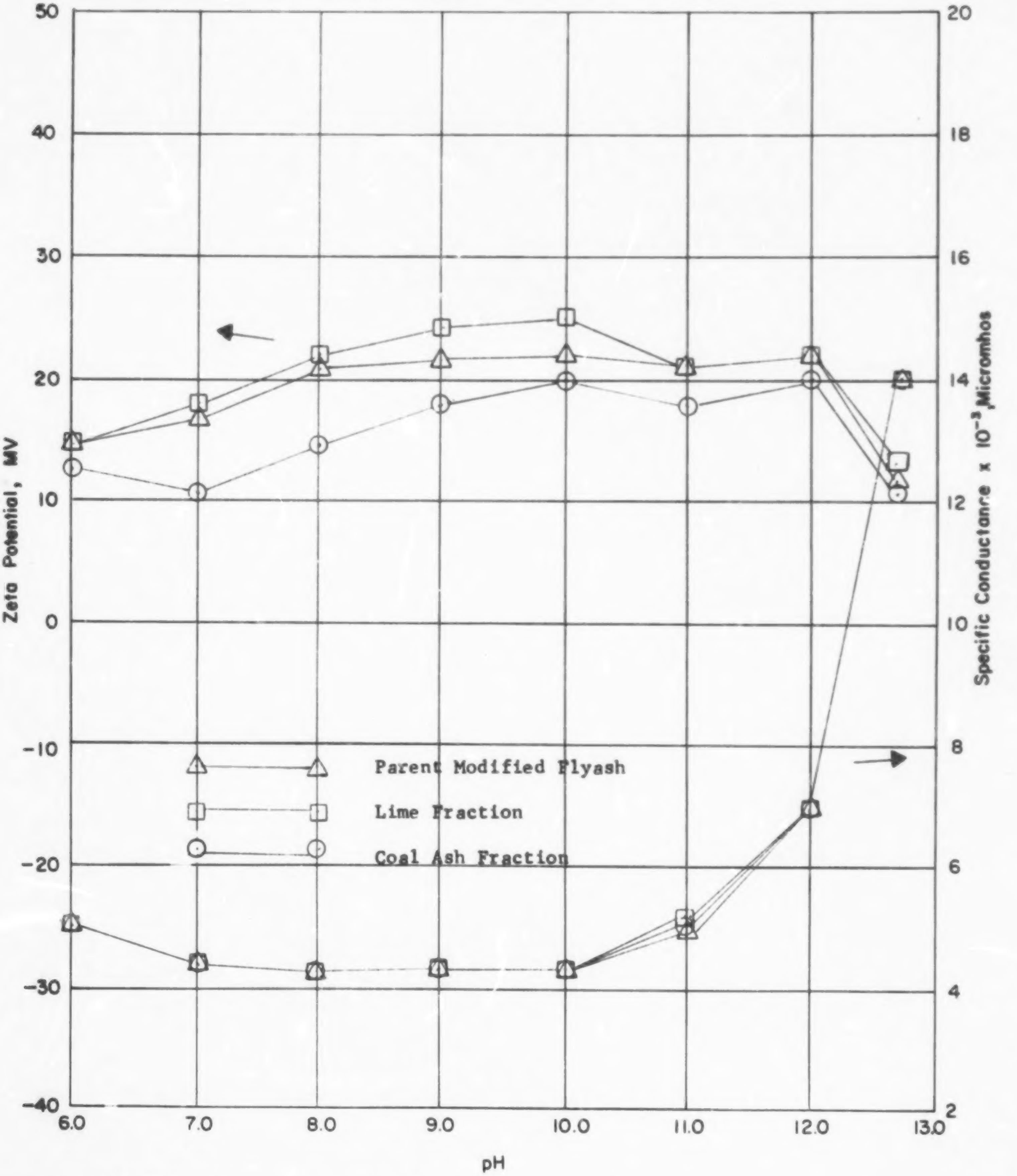


FIGURE 22B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS BY LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1 POUND PER TON OF DIVALENT SULFUR AS A SODIUM SULFIDE TO A 33 PERCENT SLURRY CONCENTRATION

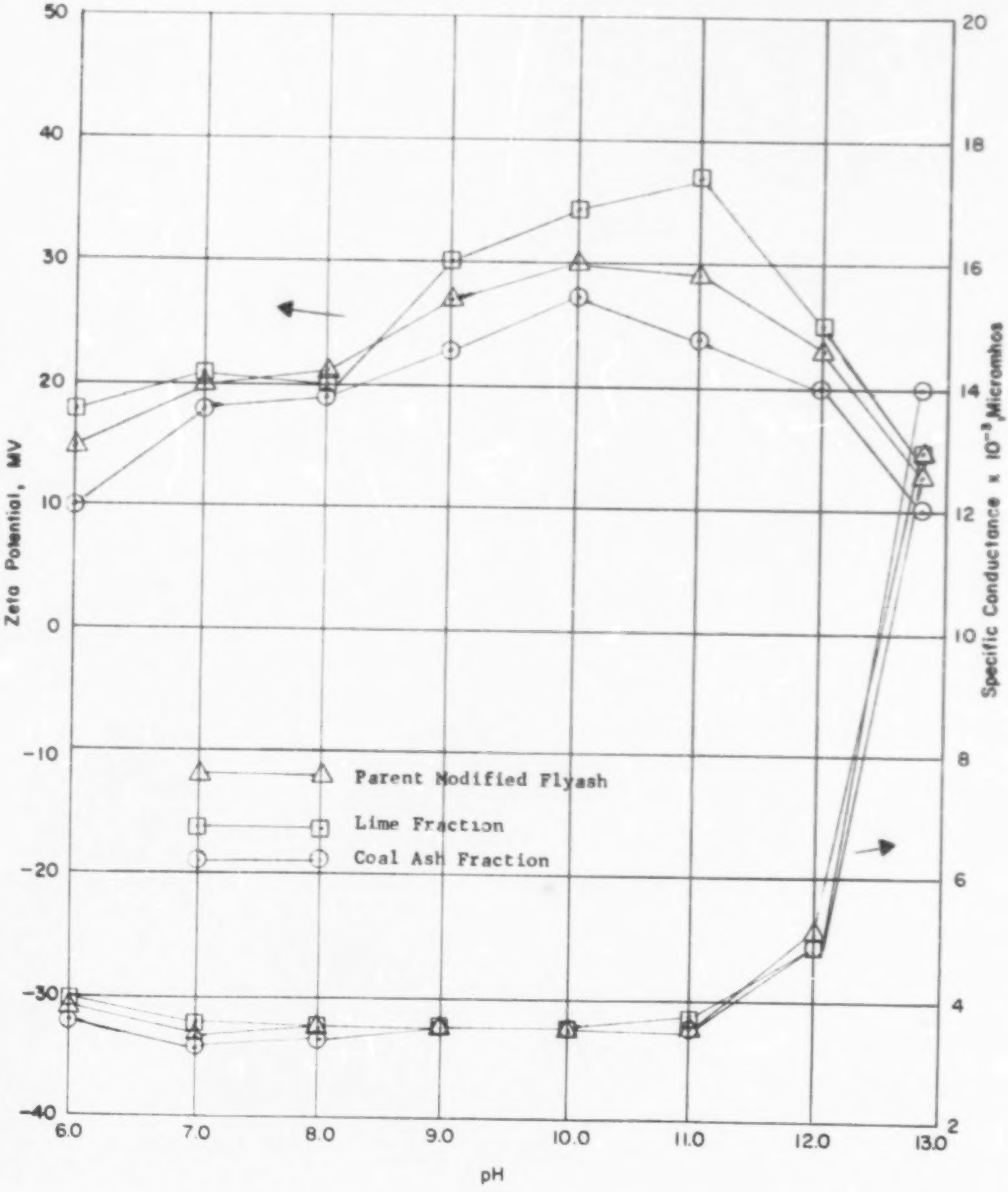


FIGURE 23B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.6 POUNDS PER TON OF DIVALENT SULFUR AS SODIUM SULFIDE TO A 33 PERCENT SLURRY CONCENTRATION.

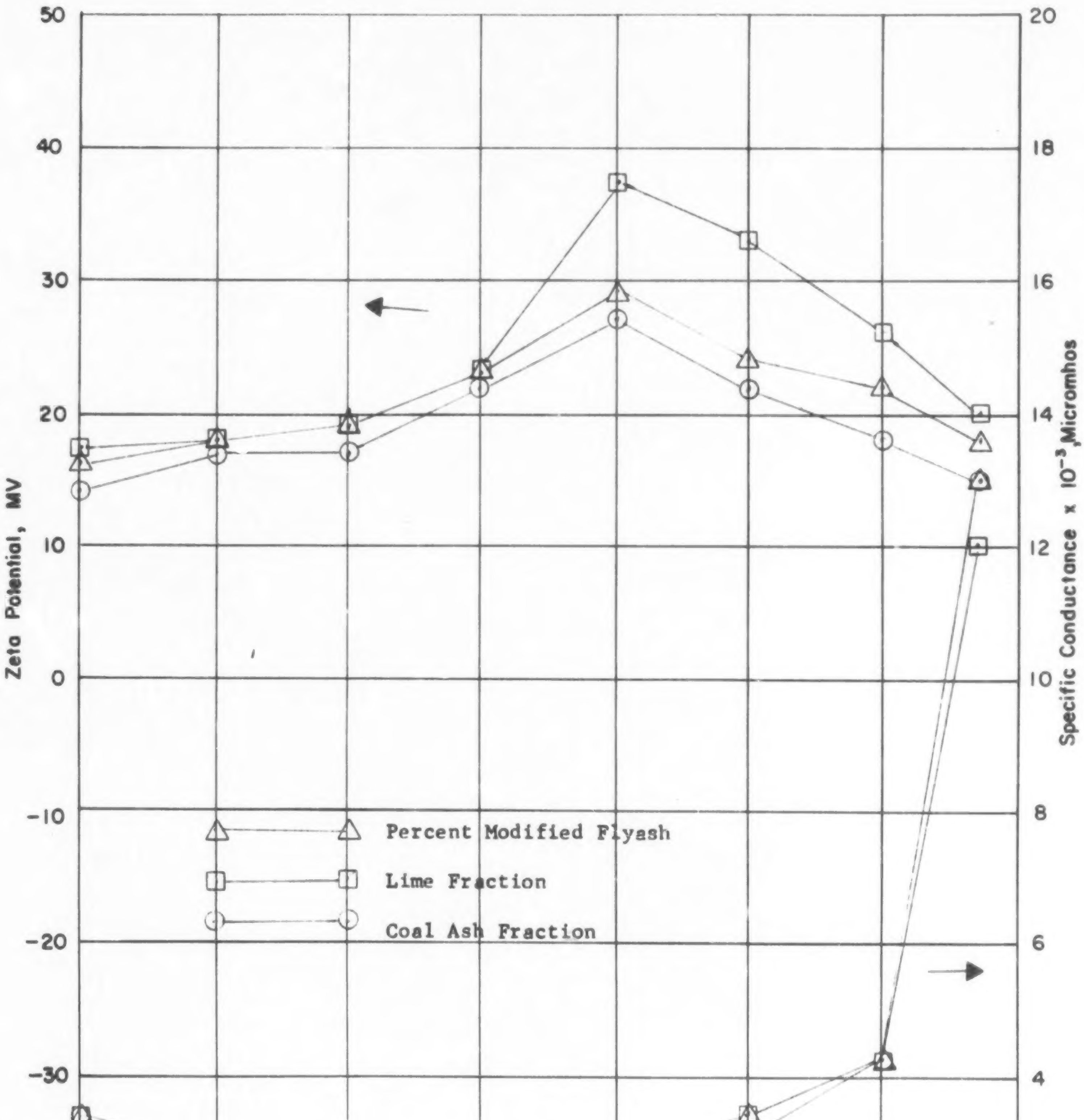


FIGURE 24B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.2 POUNDS PER TON OF DIVALENT SULFUR AS SODIUM SULFIDE TO A 33 PERCENT SLURRY CONCENTRATION

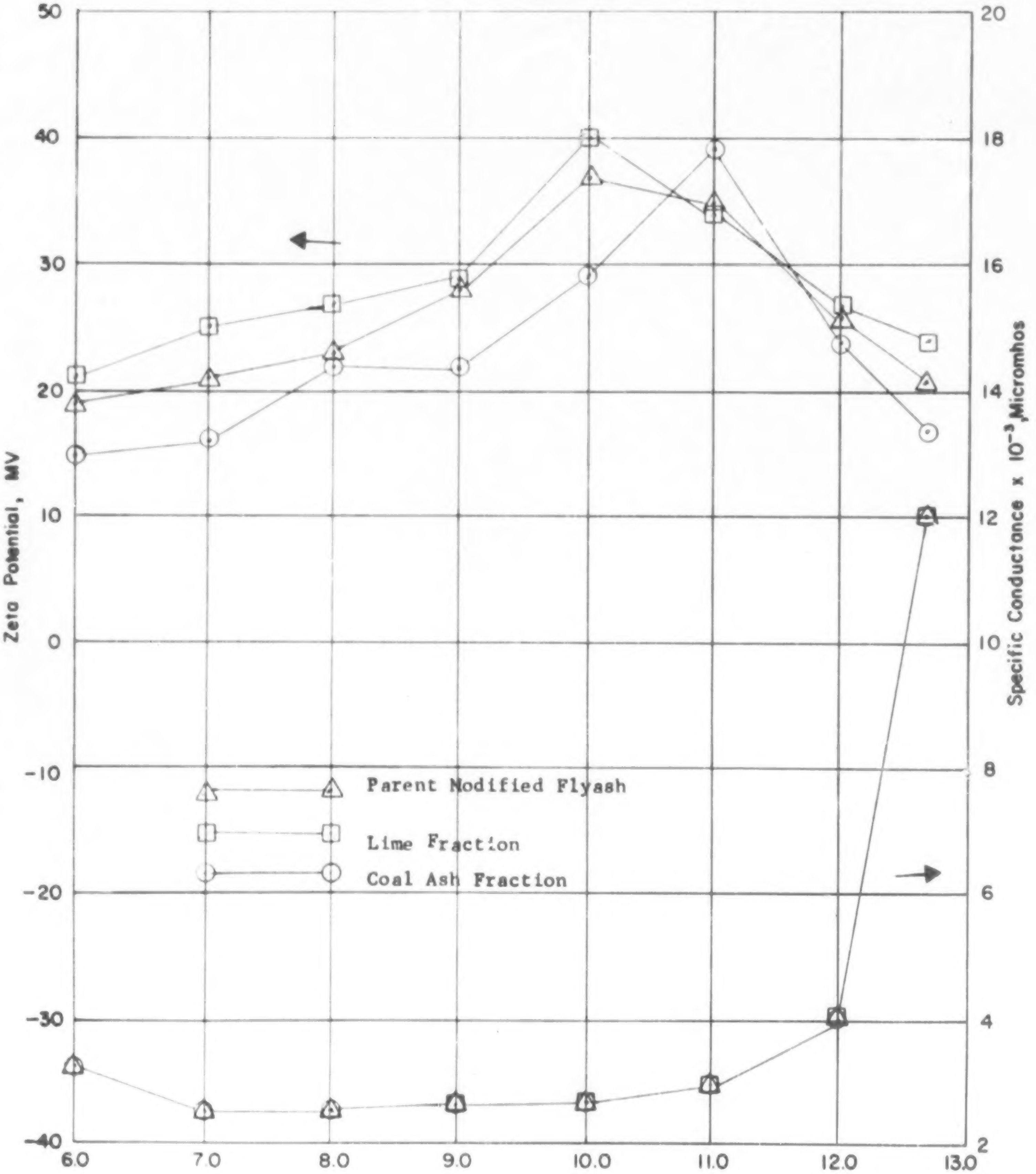


FIGURE 25B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.1 POUNDS PER TON OF DIVALENT SULFUR AS SODIUM SULFIDE TO A 33 PERCENT SLURRY CONCENTRATION

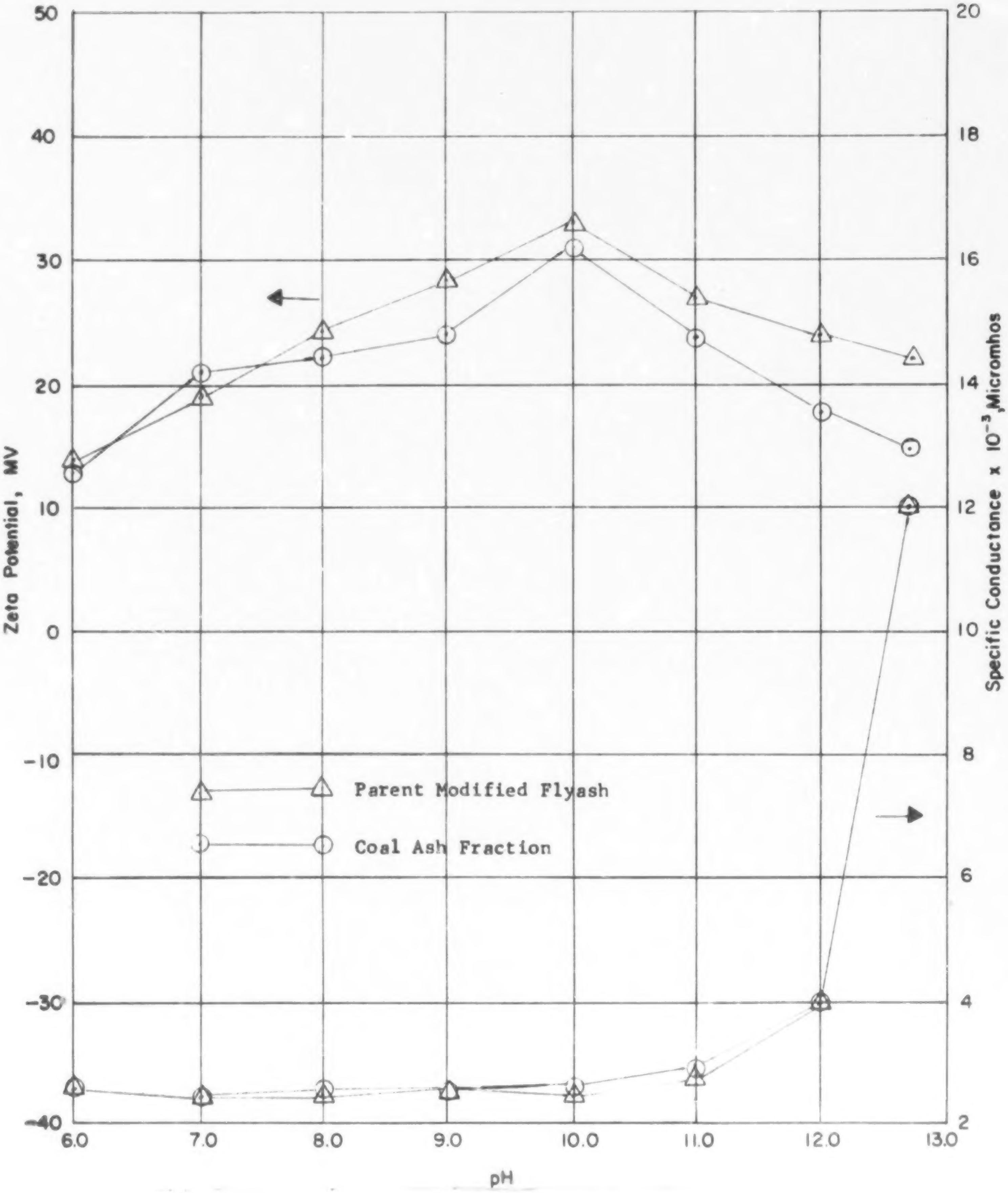


FIGURE 26B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 4 POUNDS PER TON OF DIVALENT IRON AS FERROUS AMMONIUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

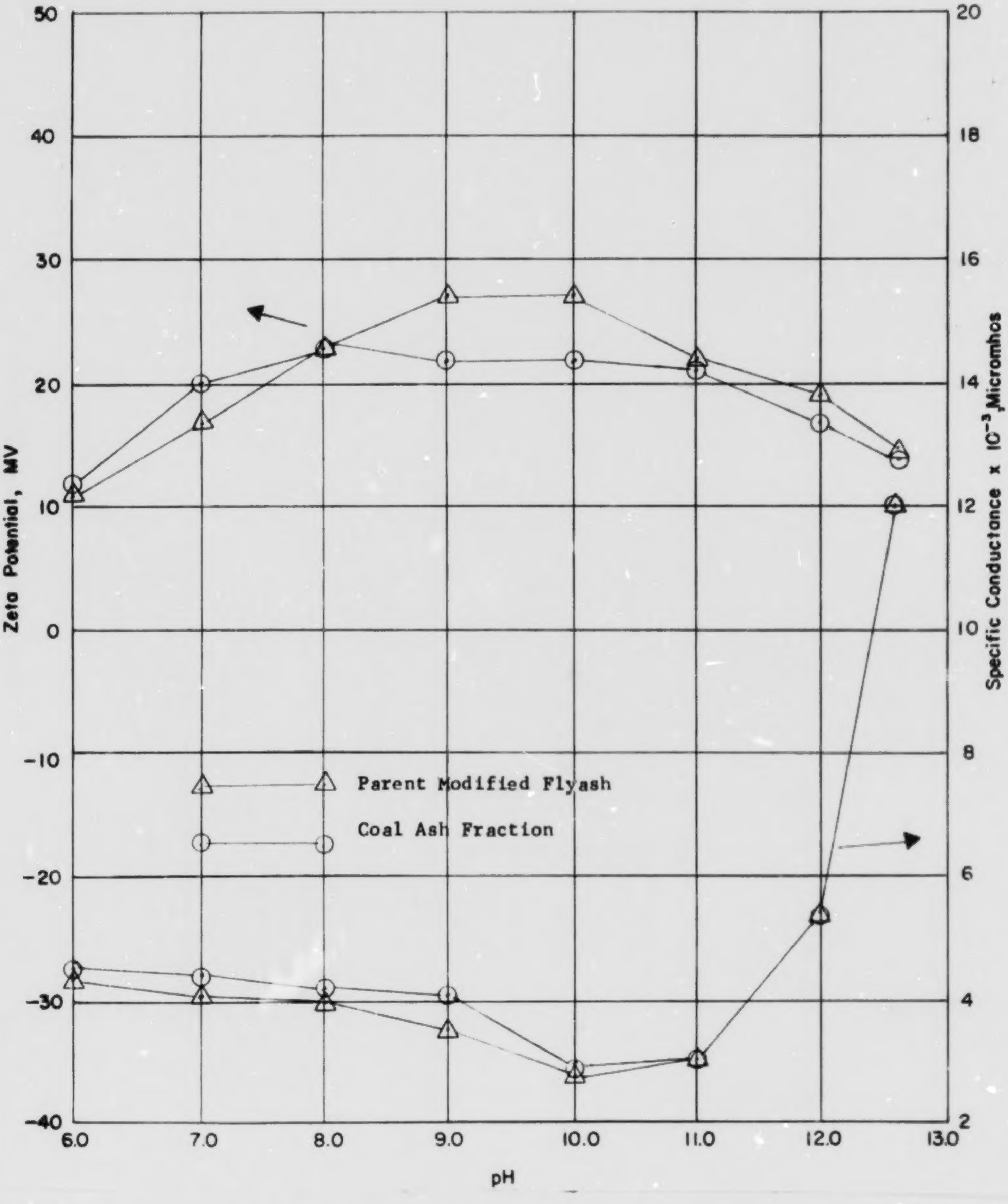


FIGURE 27B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 2 POUNDS PER TON OF DIVALENT IRON AS FERROUS AMMONIUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

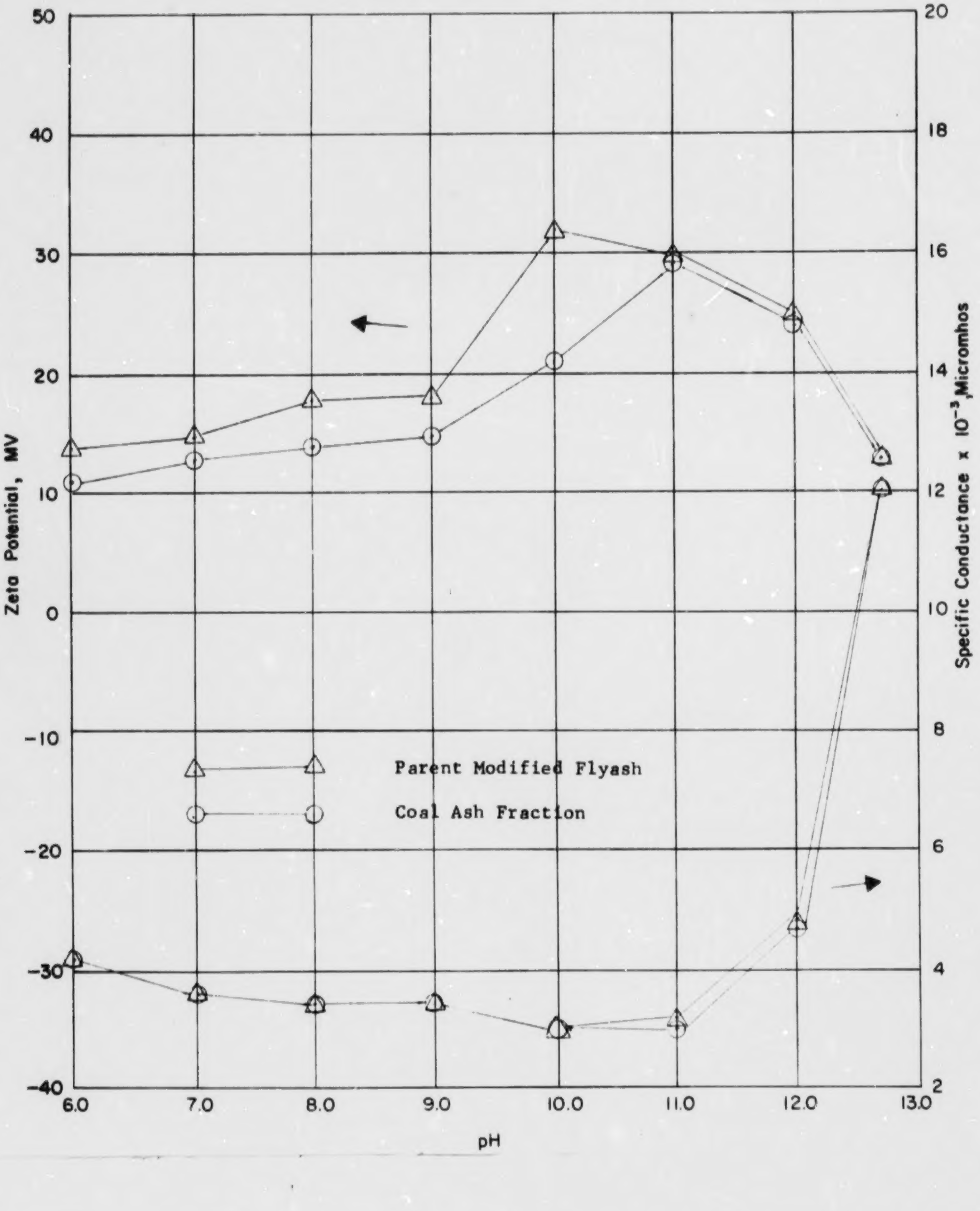


FIGURE 28B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1 POUND PER TON OF DIVALENT IRON AS FERROUS AMMONIUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

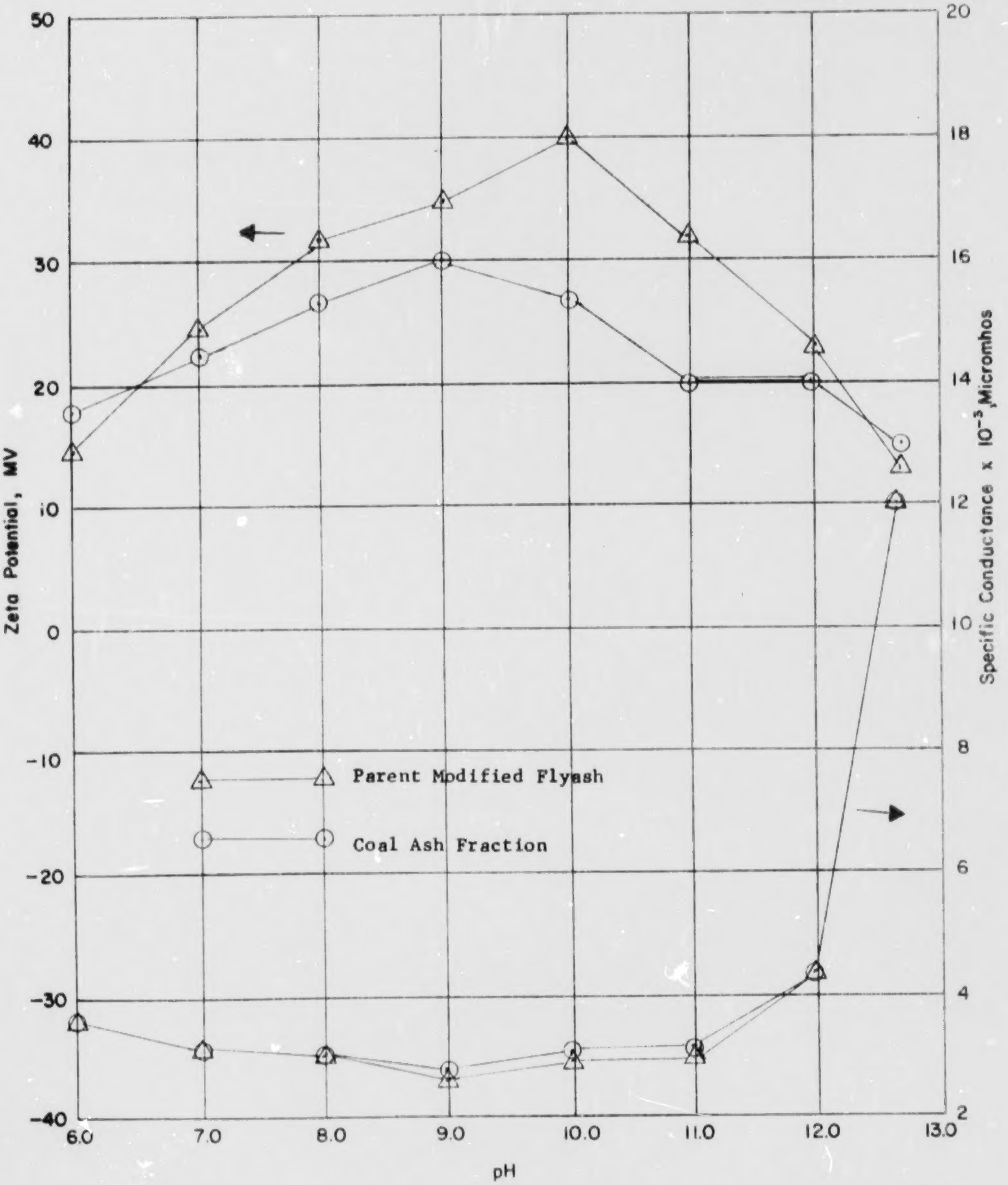


FIGURE 29B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.6 POUNDS PER TON OF DIVALENT IRON AS FERROUS AMMONIUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

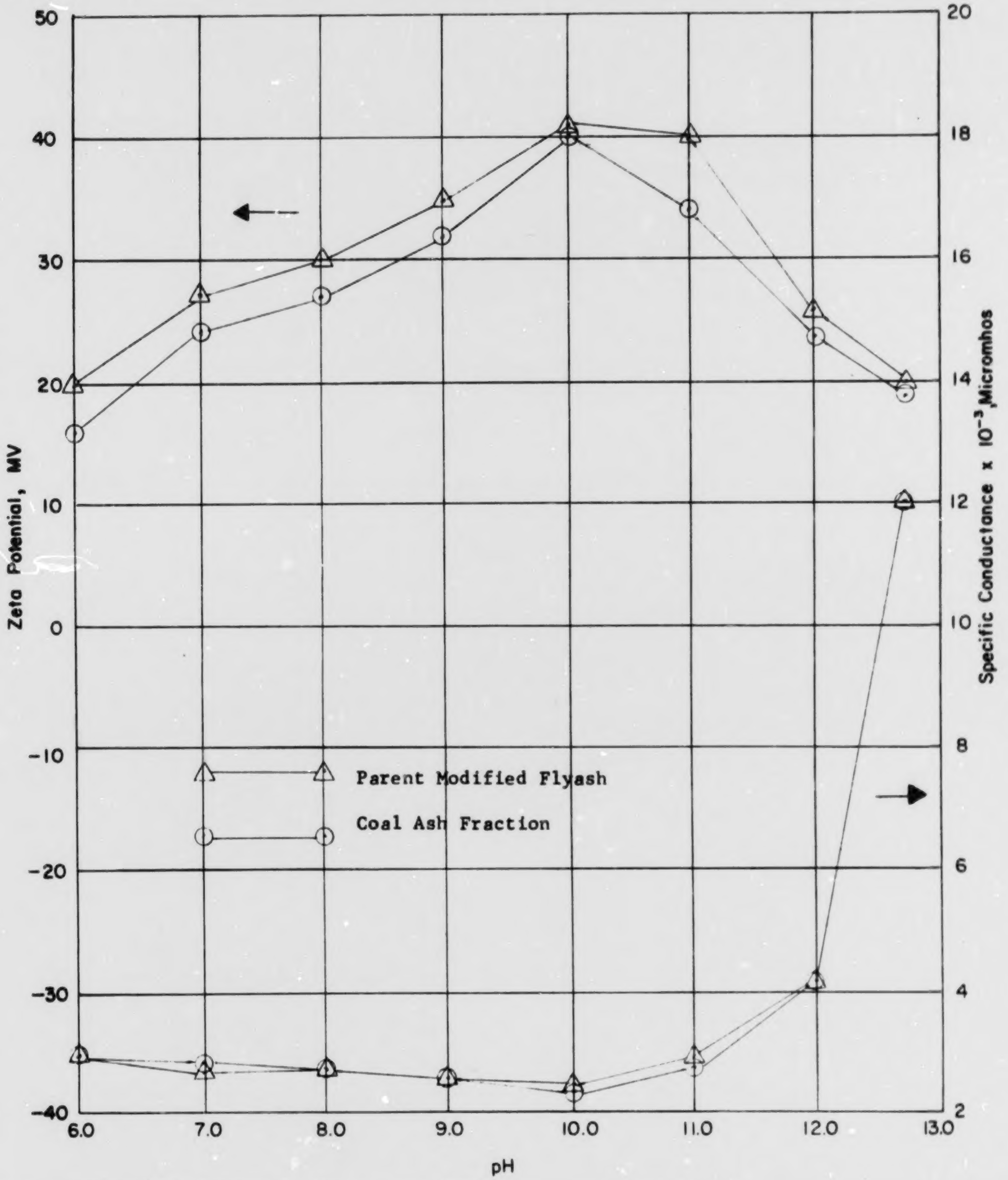


FIGURE 30B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.2 POUNDS PER TON OF DIVALENT IRON AS FERROUS AMMONIUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

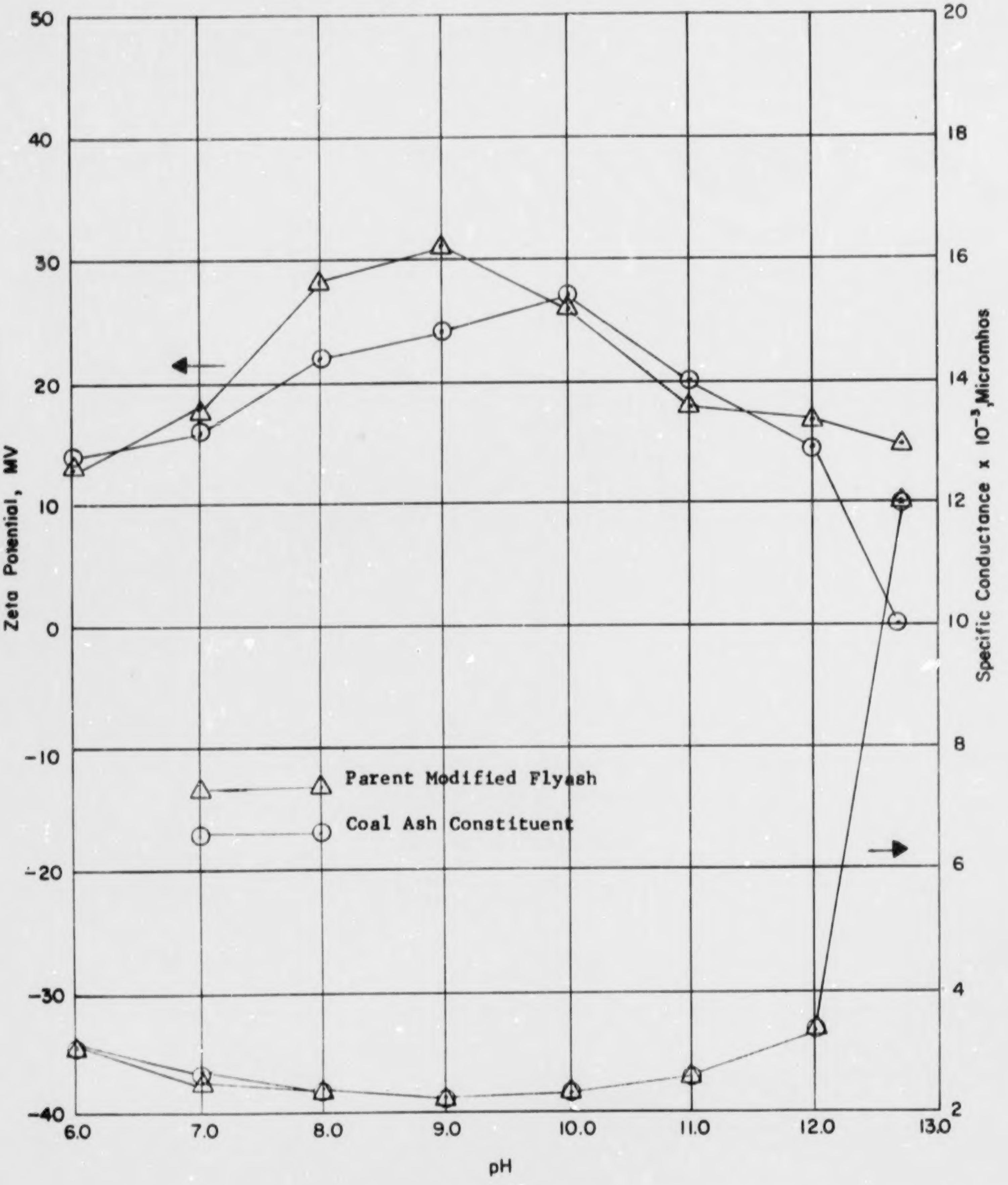


FIGURE 31B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1 POUND PER TON OF DIVALENT IRON AS FERROUS AMMONIUM SULFATE TO A 16.6 PERCENT SLURRY CONCENTRATION

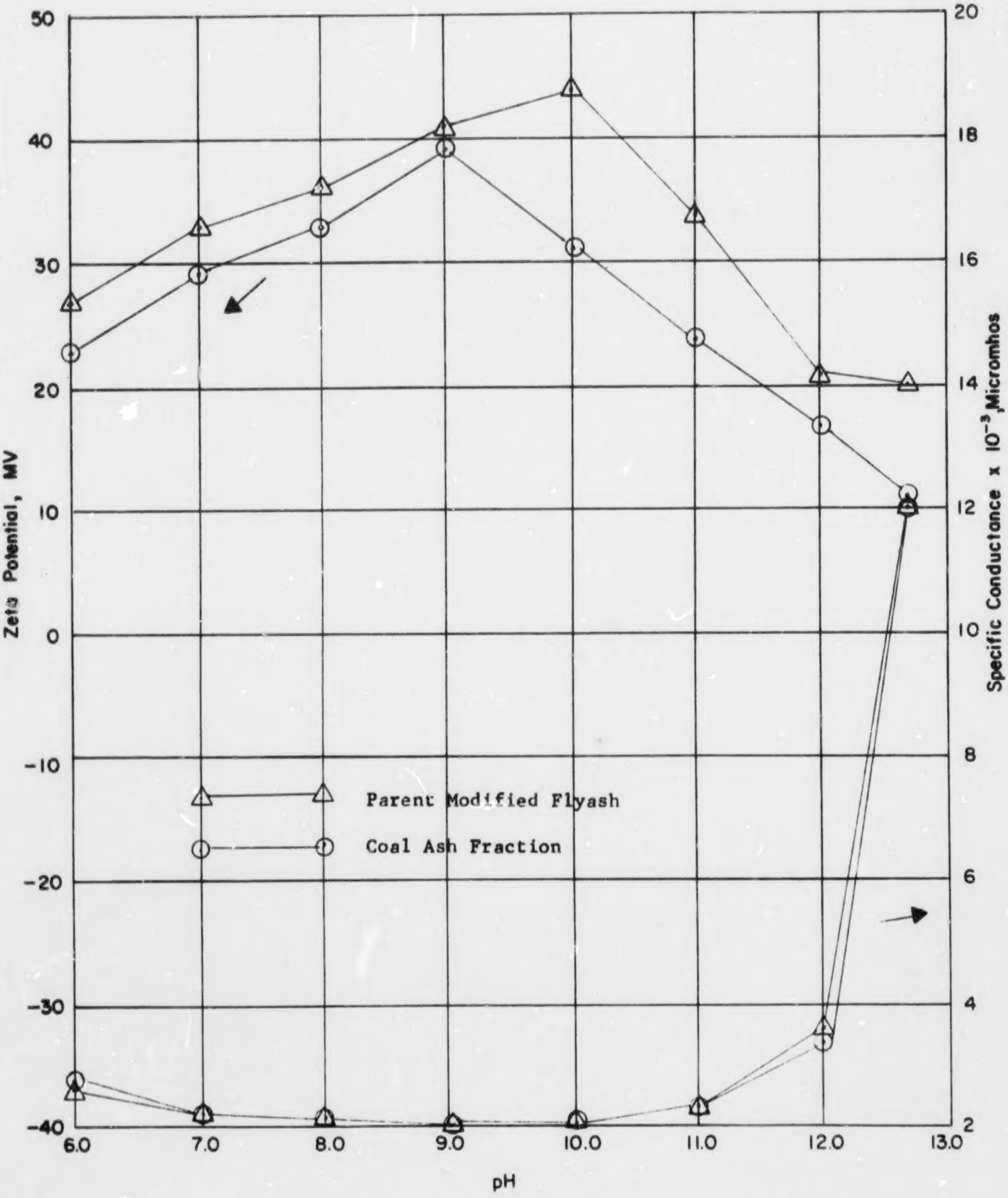


FIGURE 32B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1 POUND PER TON OF DIVALENT IRON AS FERROUS AMMONIUM SULFATE TO A 8.3 PERCENT SLURRY CONCENTRATION

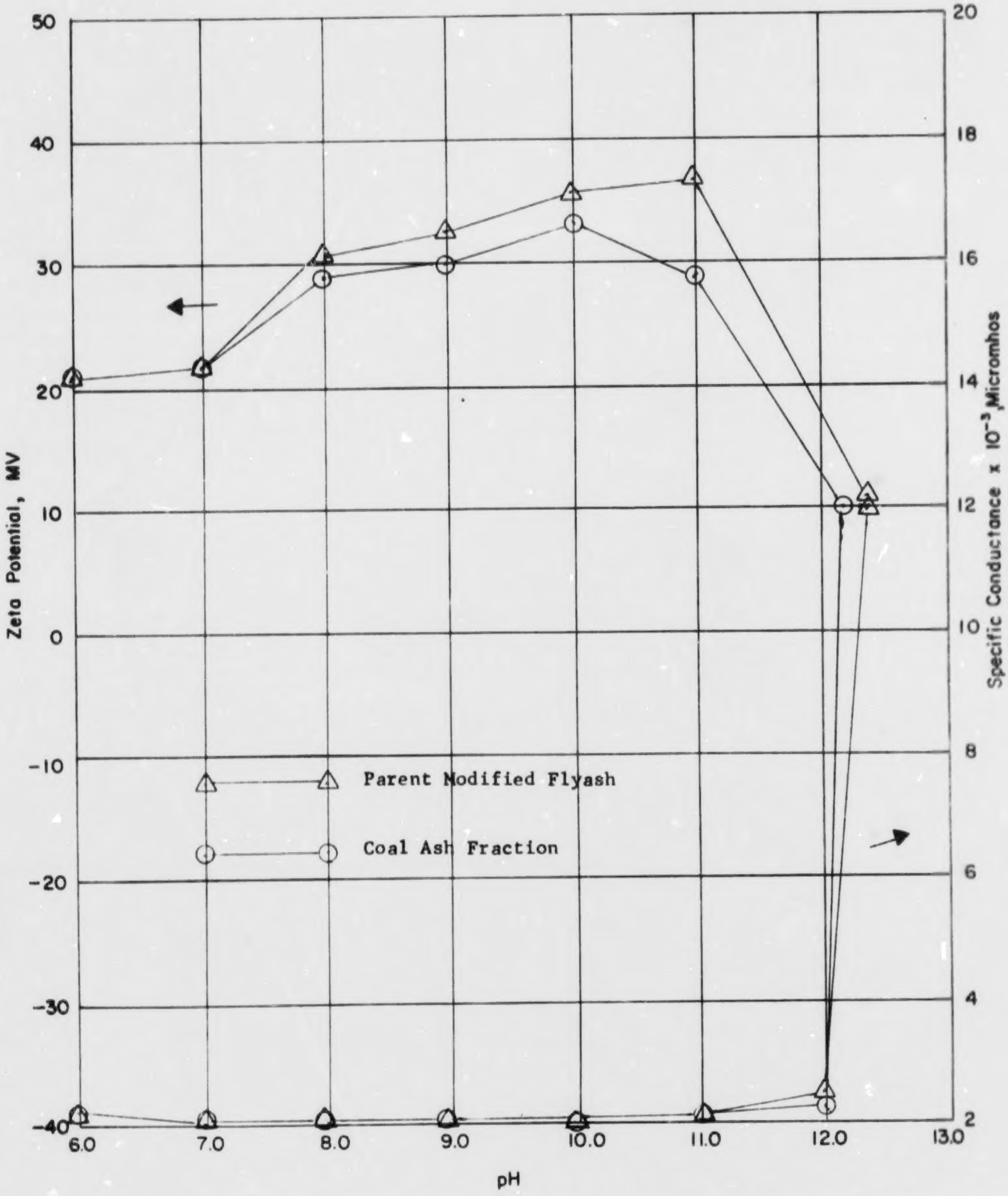


FIGURE 33B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 4 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

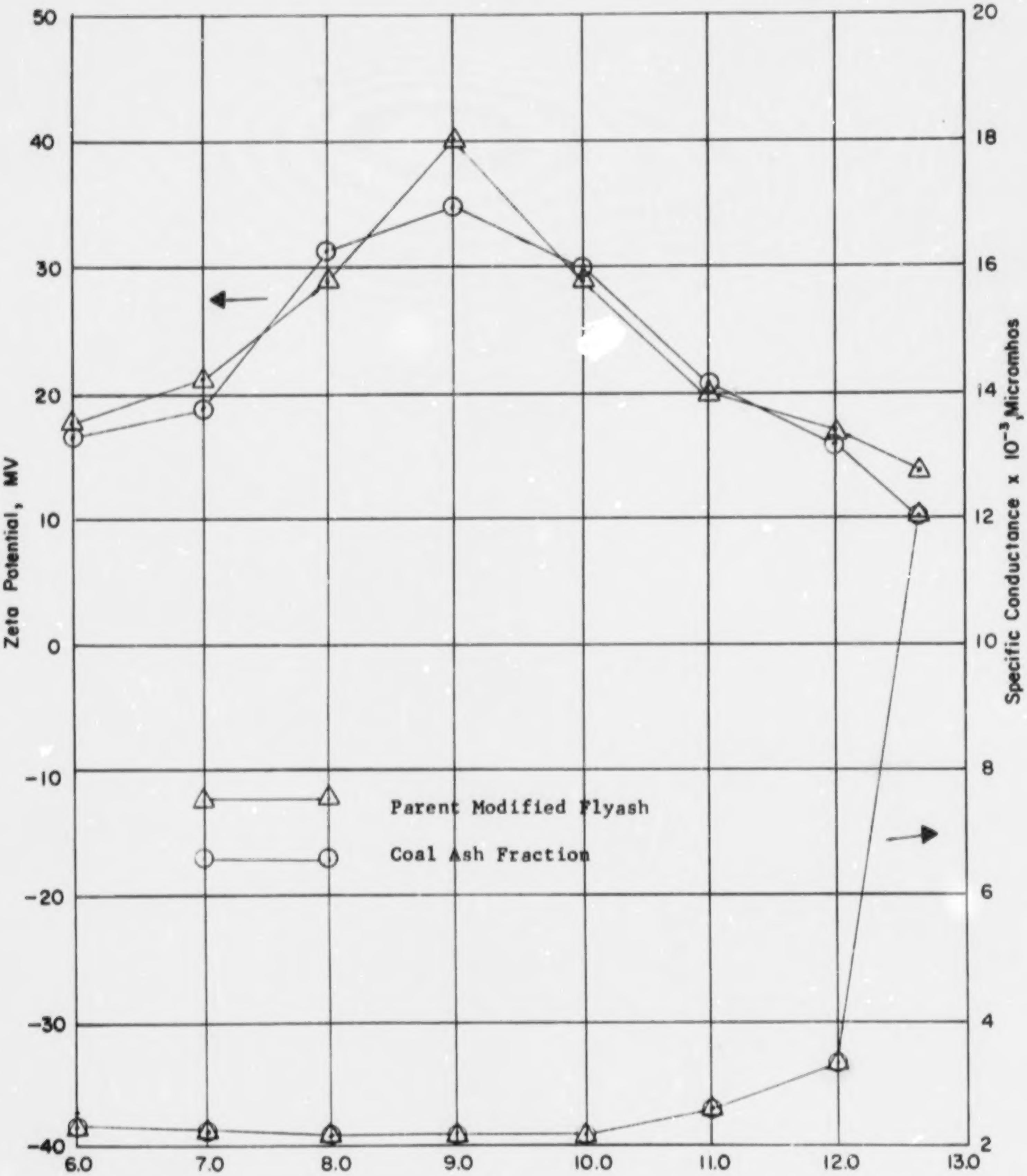


FIGURE 34B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 2 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

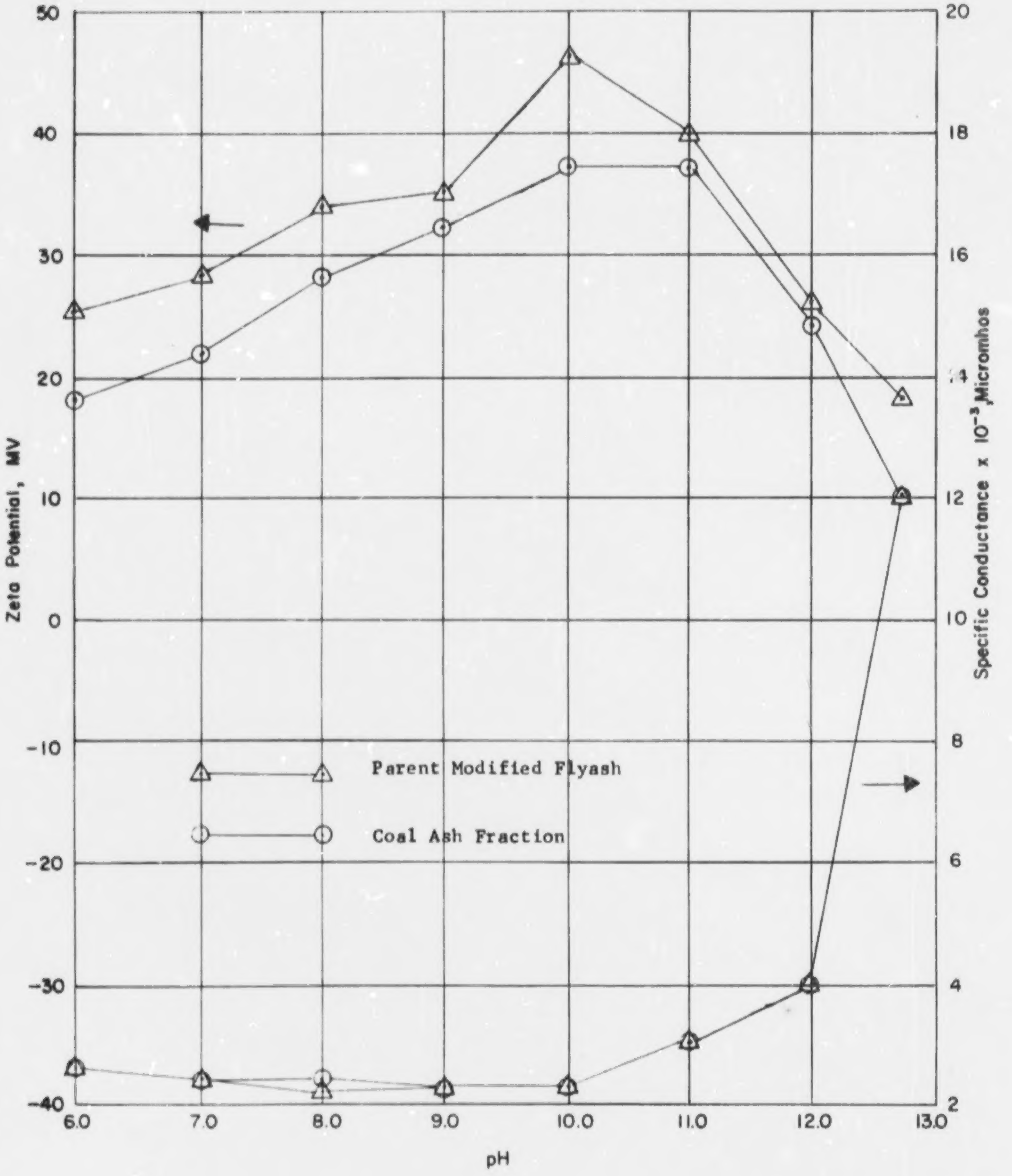


FIGURE 35B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1 POUND PER TON OF TRIVALENT ALUMINUM AS ALUMINUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

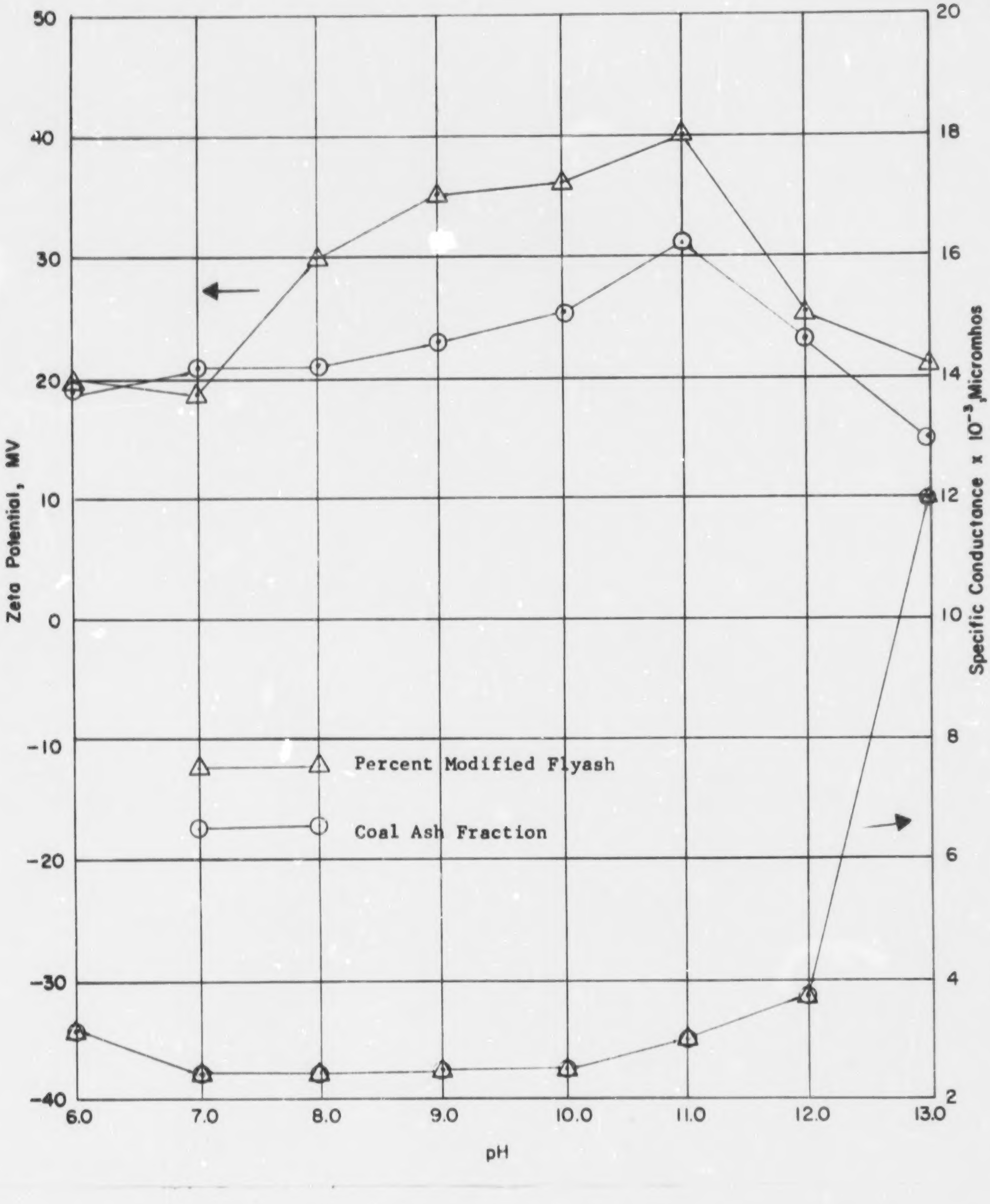


FIGURE 36B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.6 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

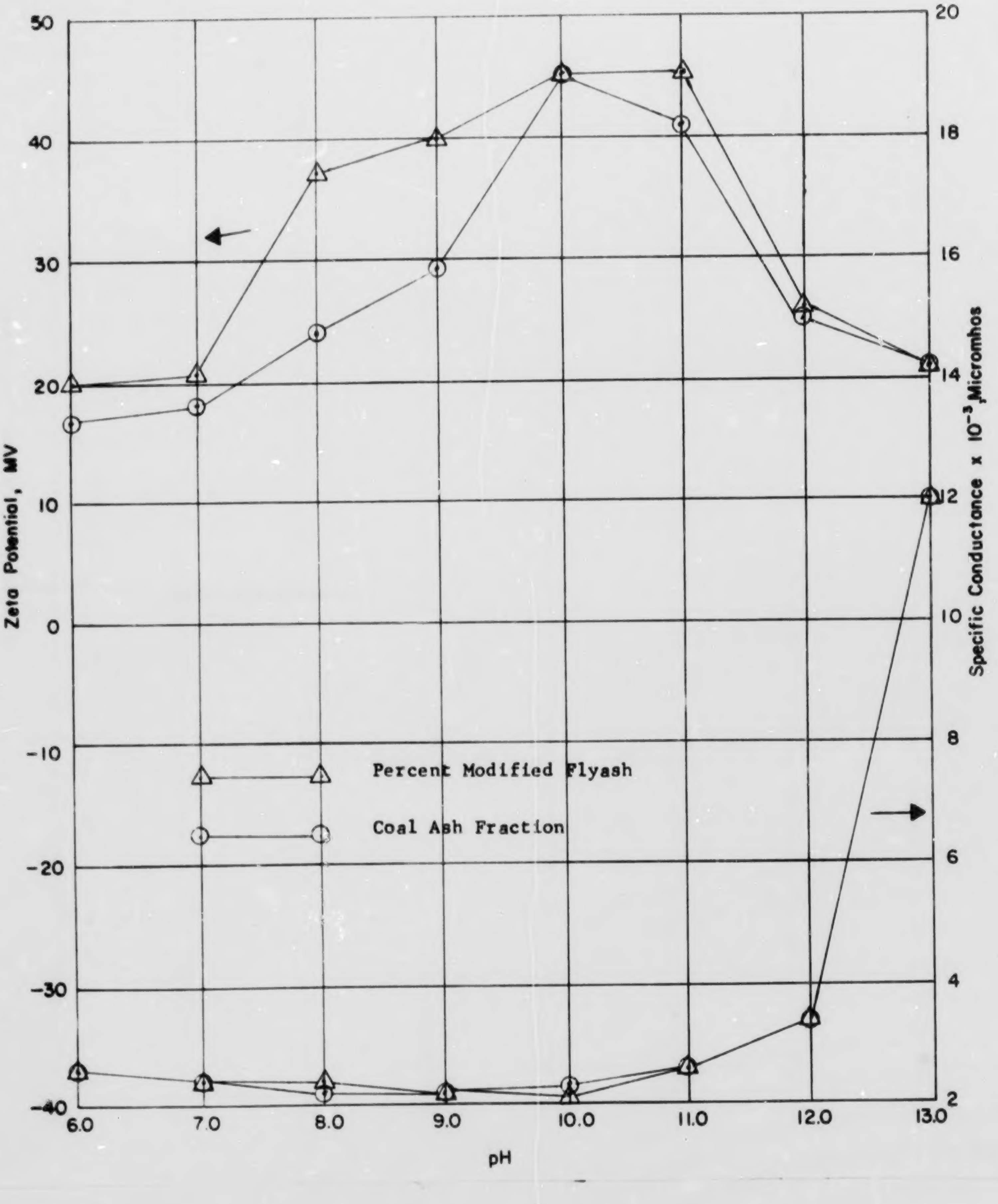


FIGURE 37B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.2 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM SULFATE TO A 33 PERCENT SLURRY CONCENTRATION

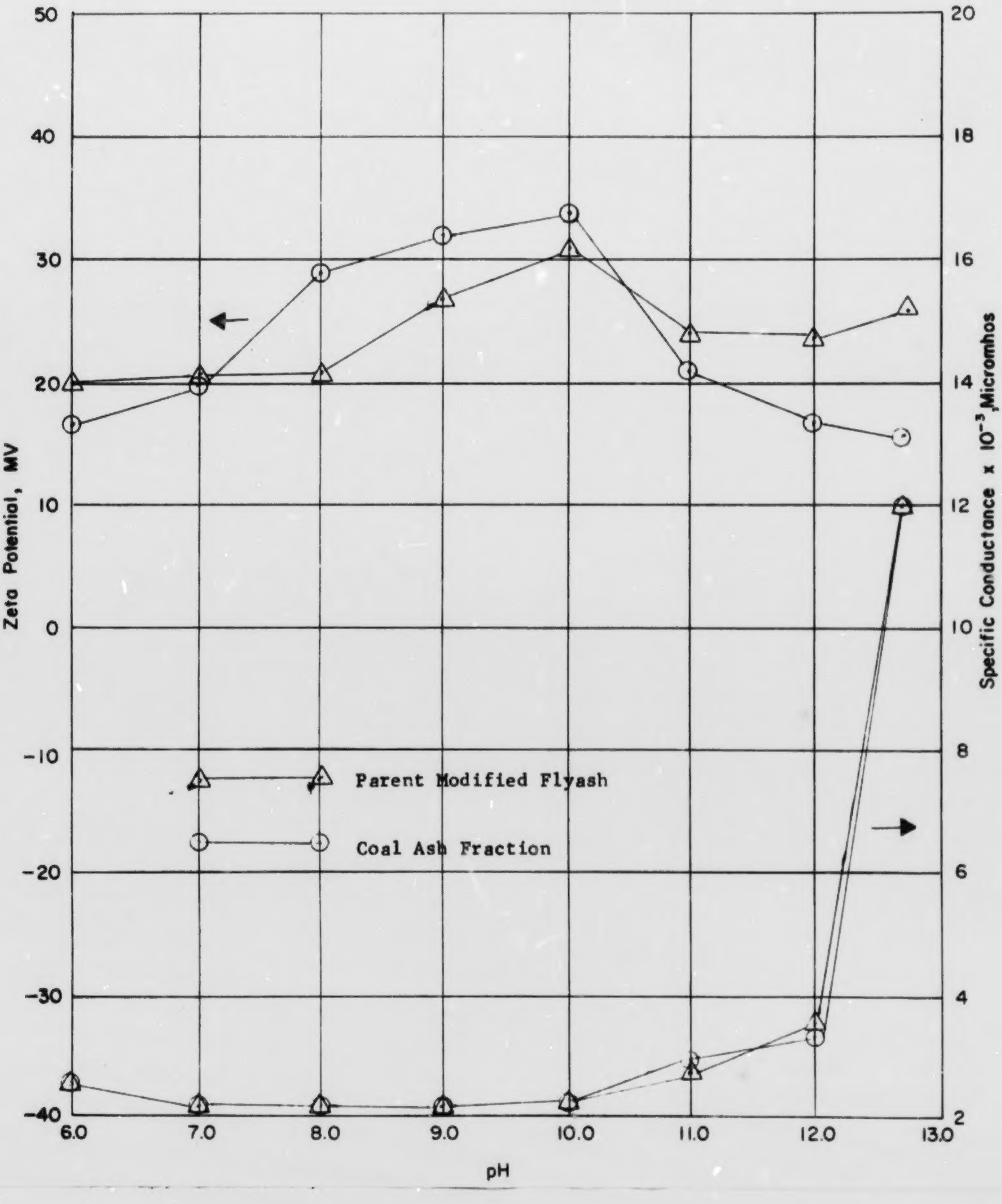


FIGURE 38B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.6 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM SULFATE TO A 16.6 PERCENT SLURRY CONCENTRATION

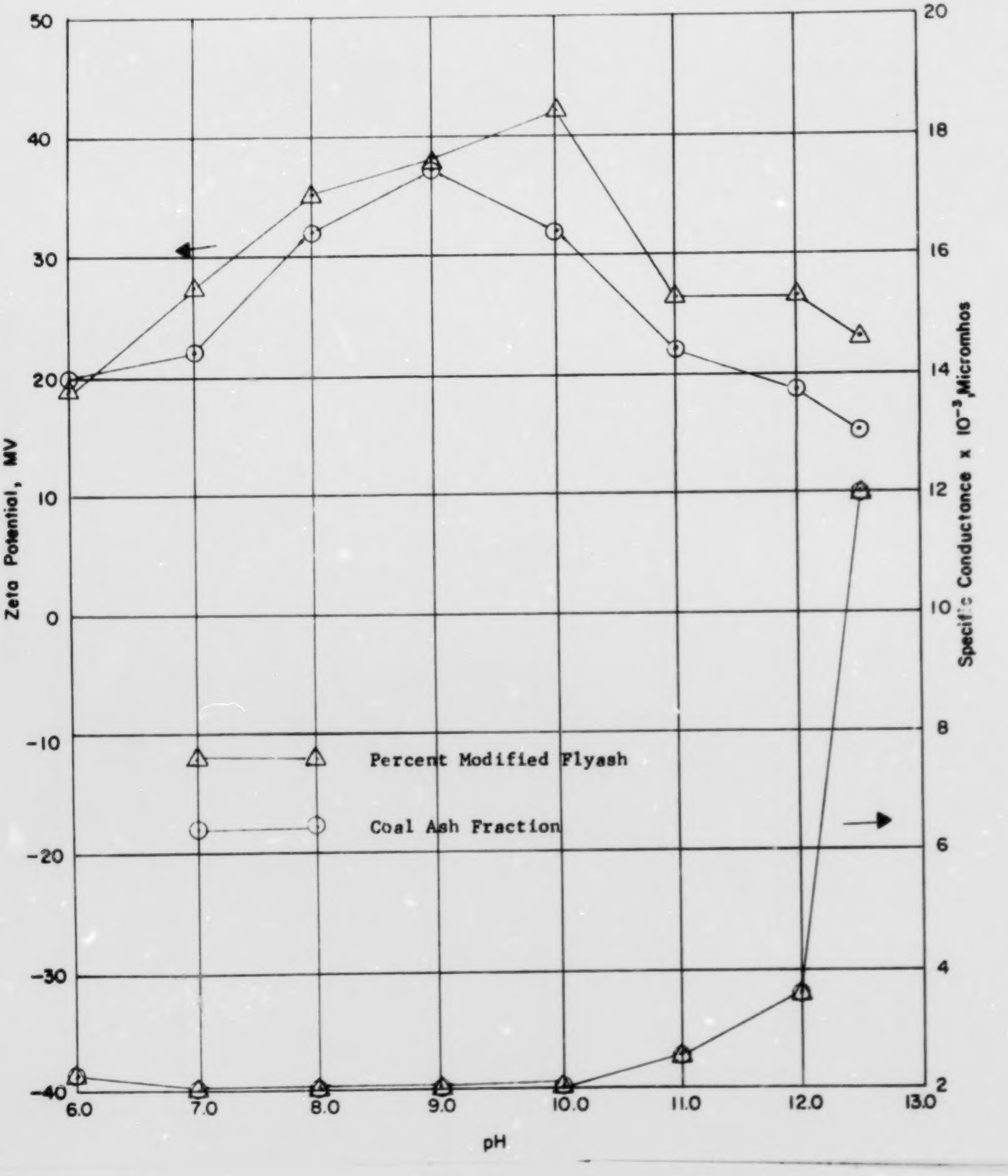


FIGURE 39B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.6 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM SULFATE TO A 8.3 PERCENT SLURRY CONCENTRATION

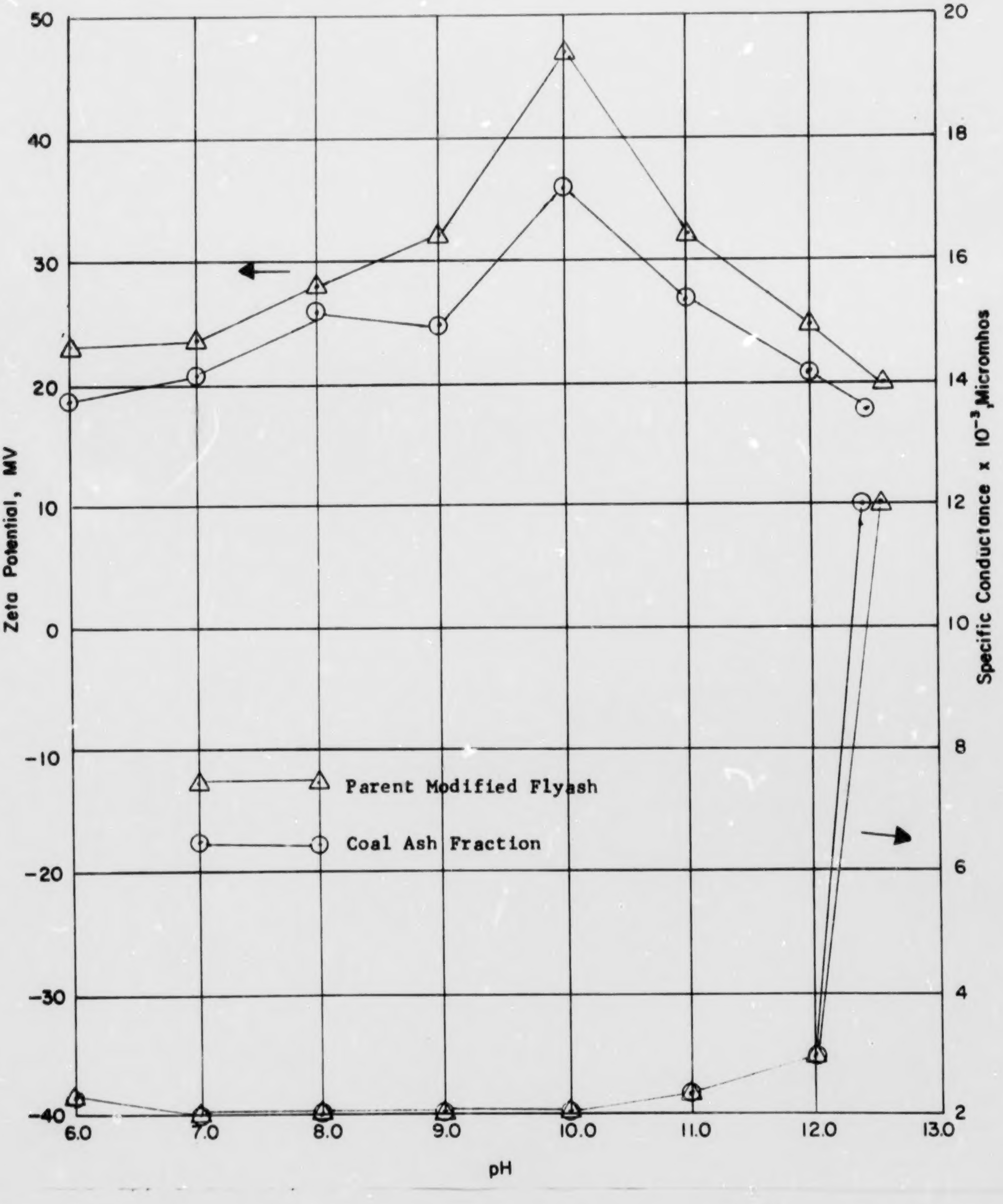


FIGURE 40B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.2 POUNDS PER TON OF TRIVALENT IRON AS FERRIC CHLORIDE TO A 33 PERCENT SLURRY CONCENTRATION

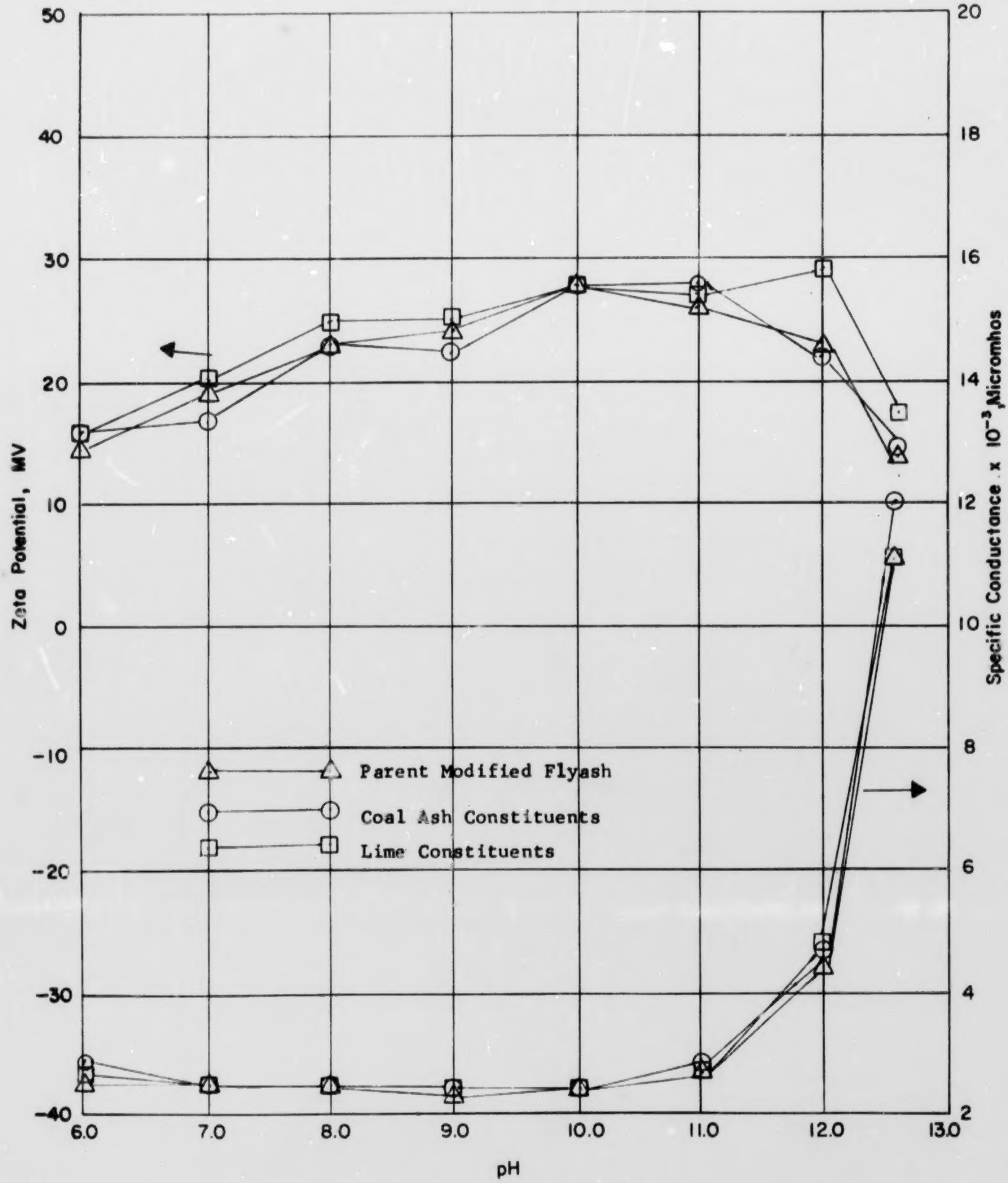


FIGURE 41B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE
OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE P1D
AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.4 POUNDS PER TON
OF TRIVALENT IRON AS FERRIC CHLORIDE
TO A 33 PERCENT SLURRY CONCENTRATION

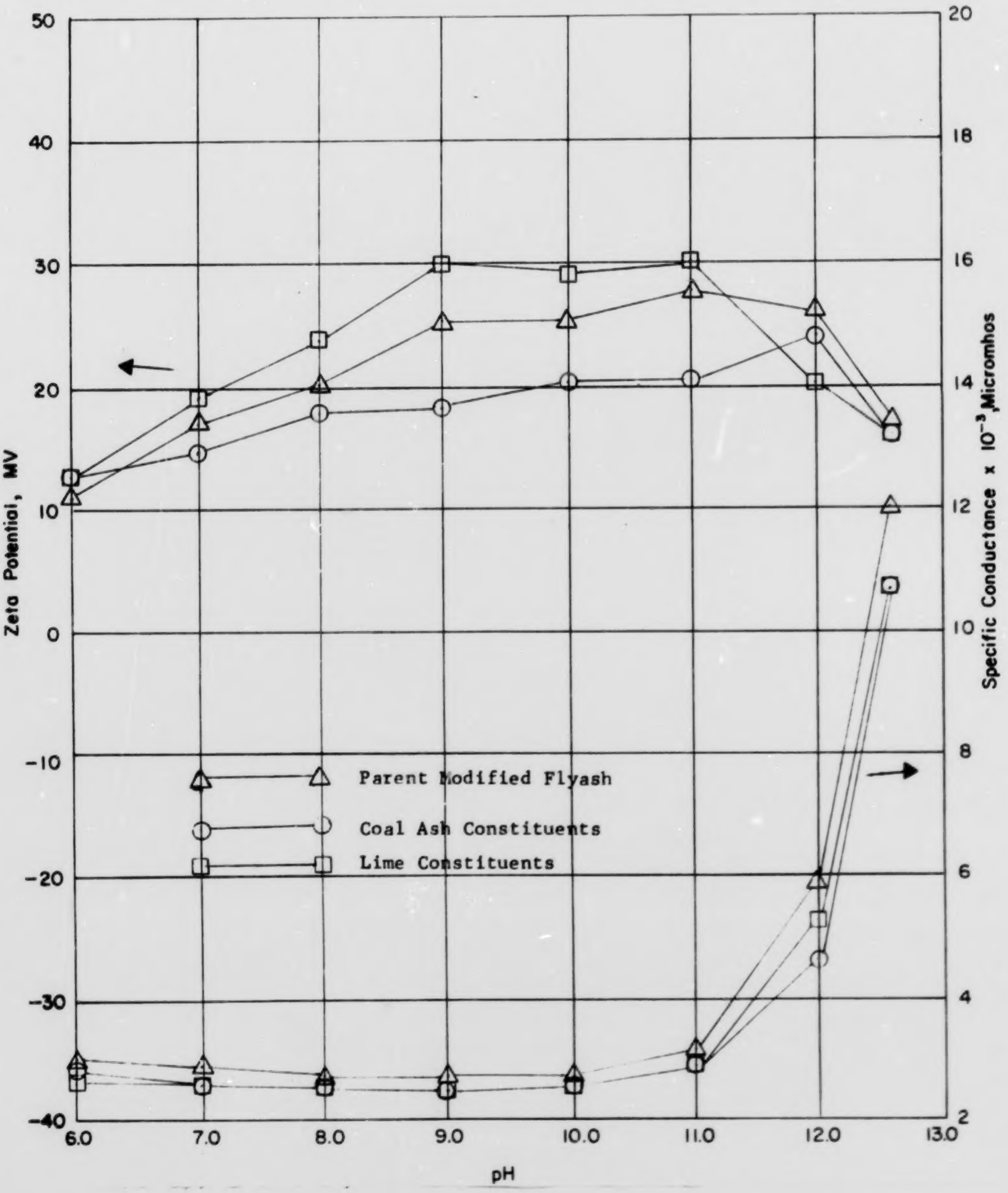


FIGURE 42B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.6 POUNDS PER TON OF TRIVALENT IRON AS FERRIC CHLORIDE TO A 33 PERCENT SLURRY CONCENTRATION

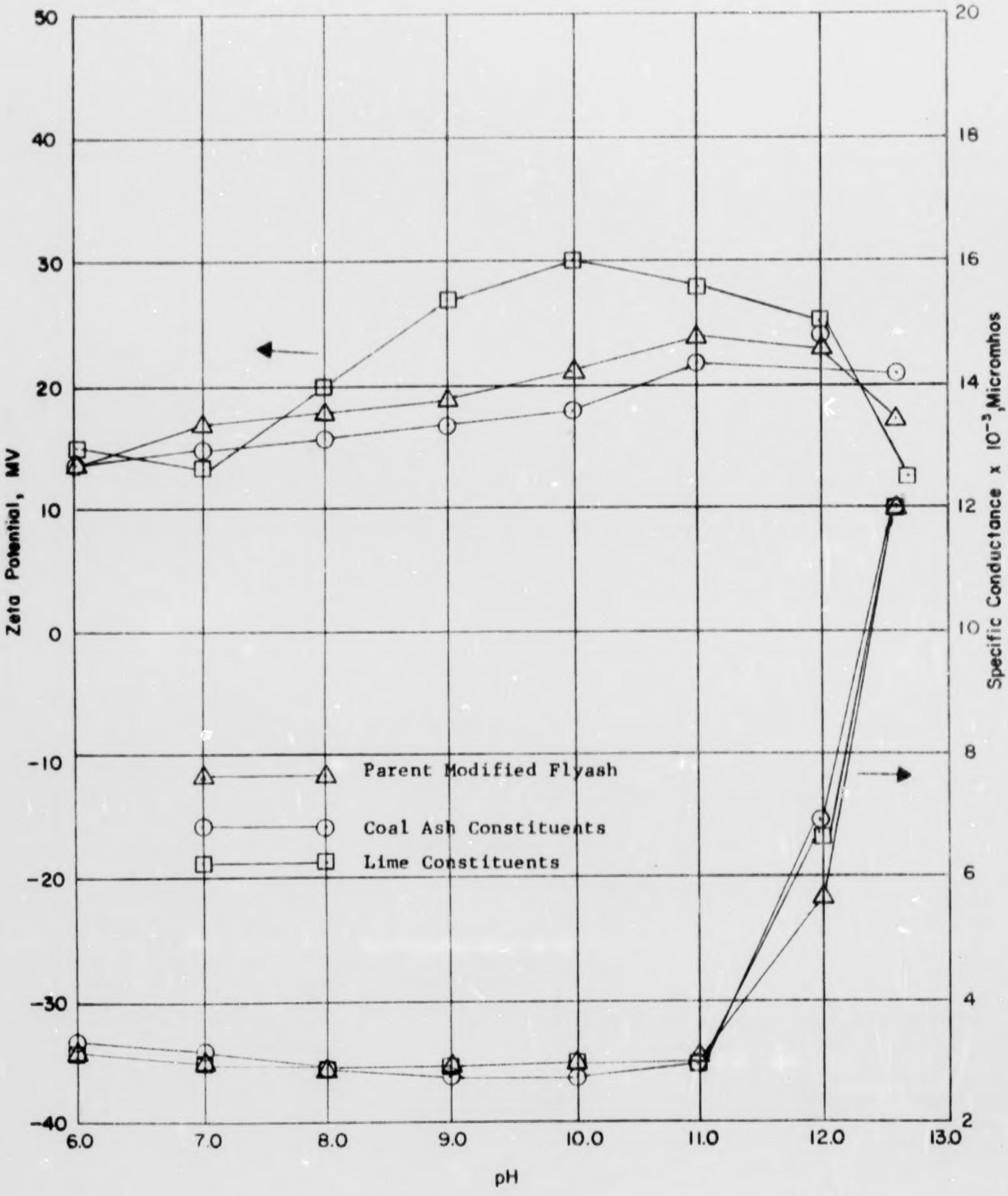


FIGURE 43B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.8 POUNDS PER TON OF TRIVALENT IRON AS FERRIC CHLORIDE TO A 33 PERCENT SLURRY CONCENTRATION

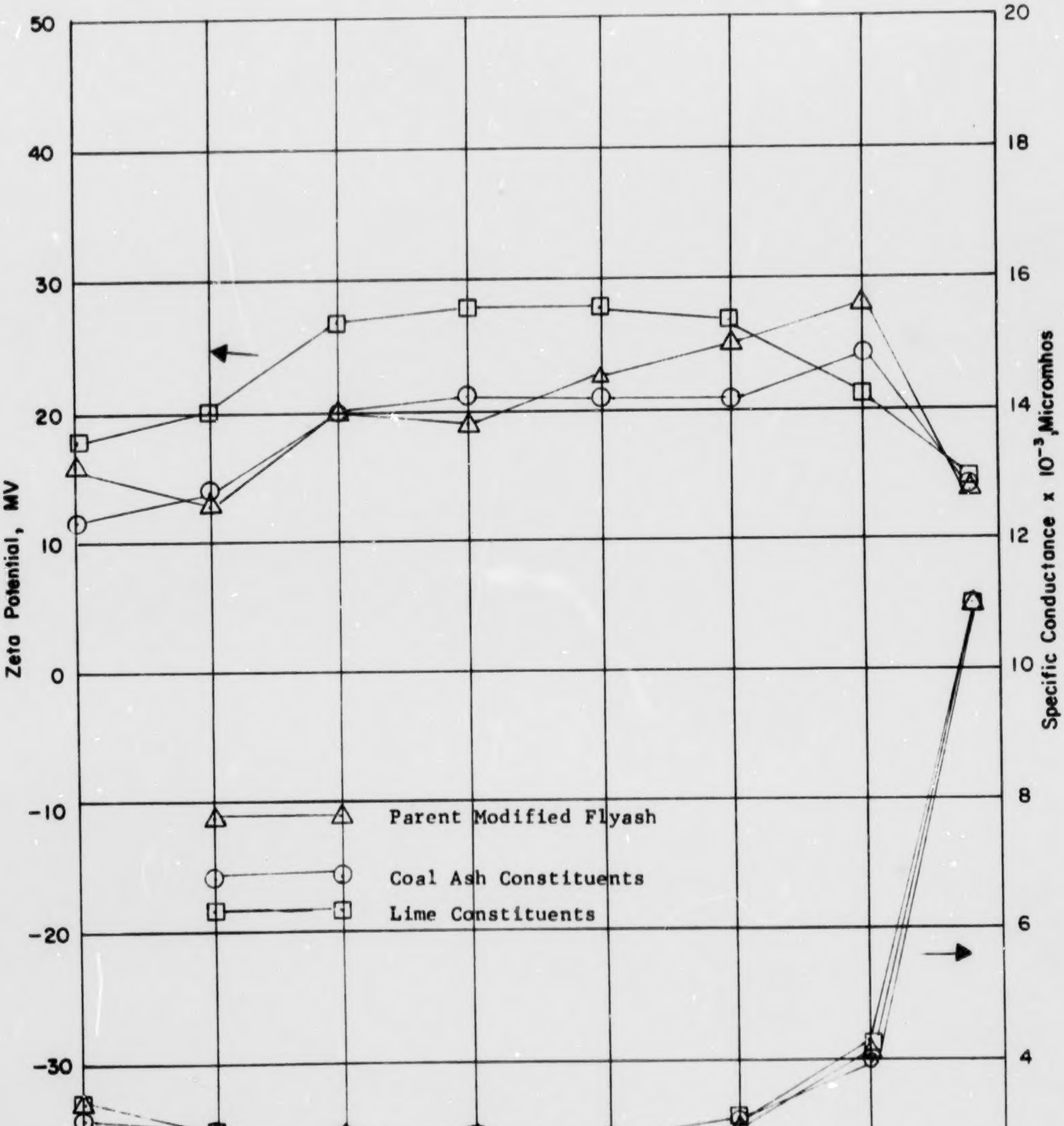


FIGURE 44B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1.0 POUND PER TON OF TRIVALENT IRON AS FERRIC CHLORIDE TO A 33 PERCENT SLURRY CONCENTRATION

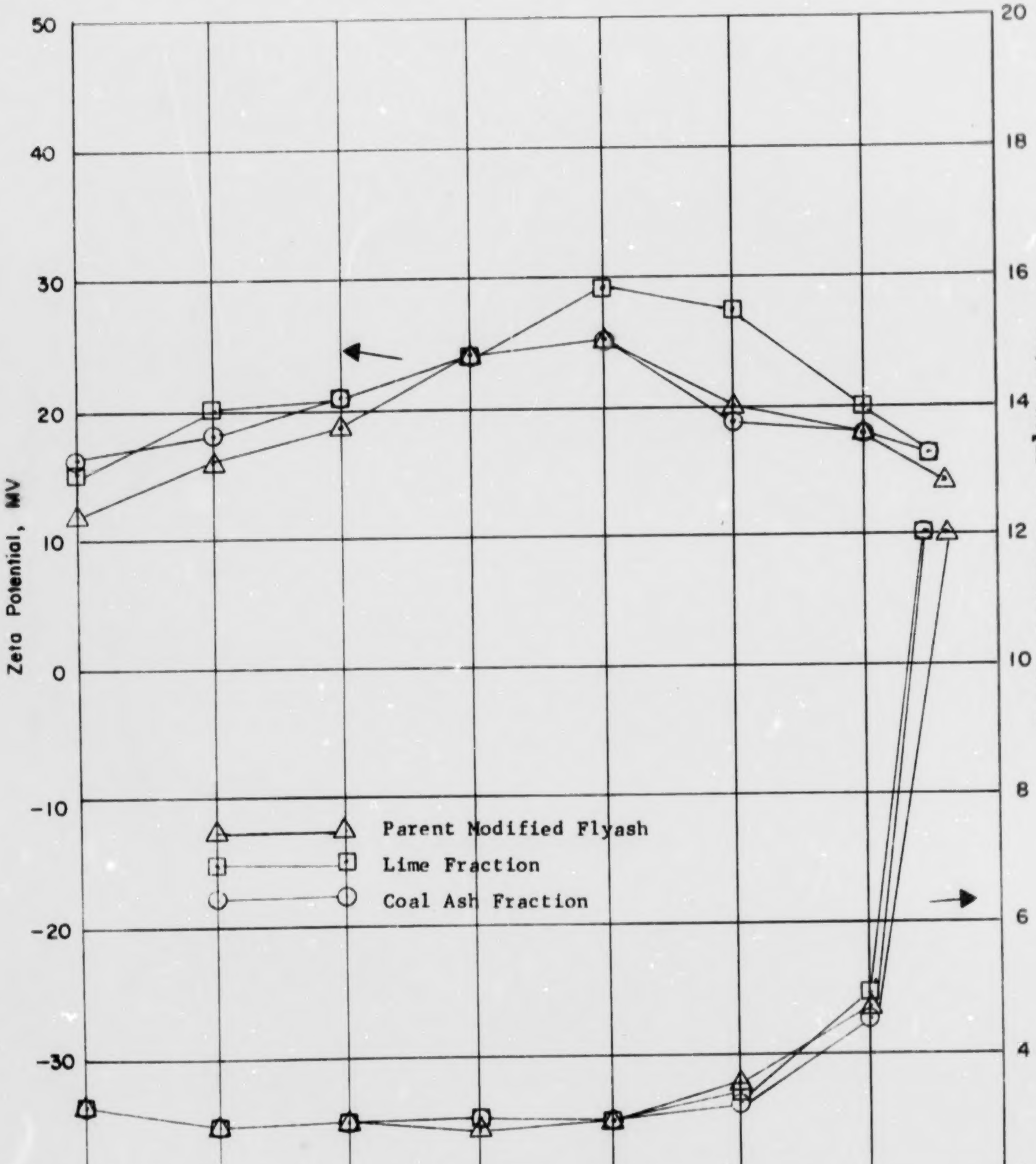


FIGURE 45B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 2.0 POUNDS PER TON OF TRIVALENT IRON AS FERRIC CHLORIDE TO A 33 PERCENT SLURRY CONCENTRATION

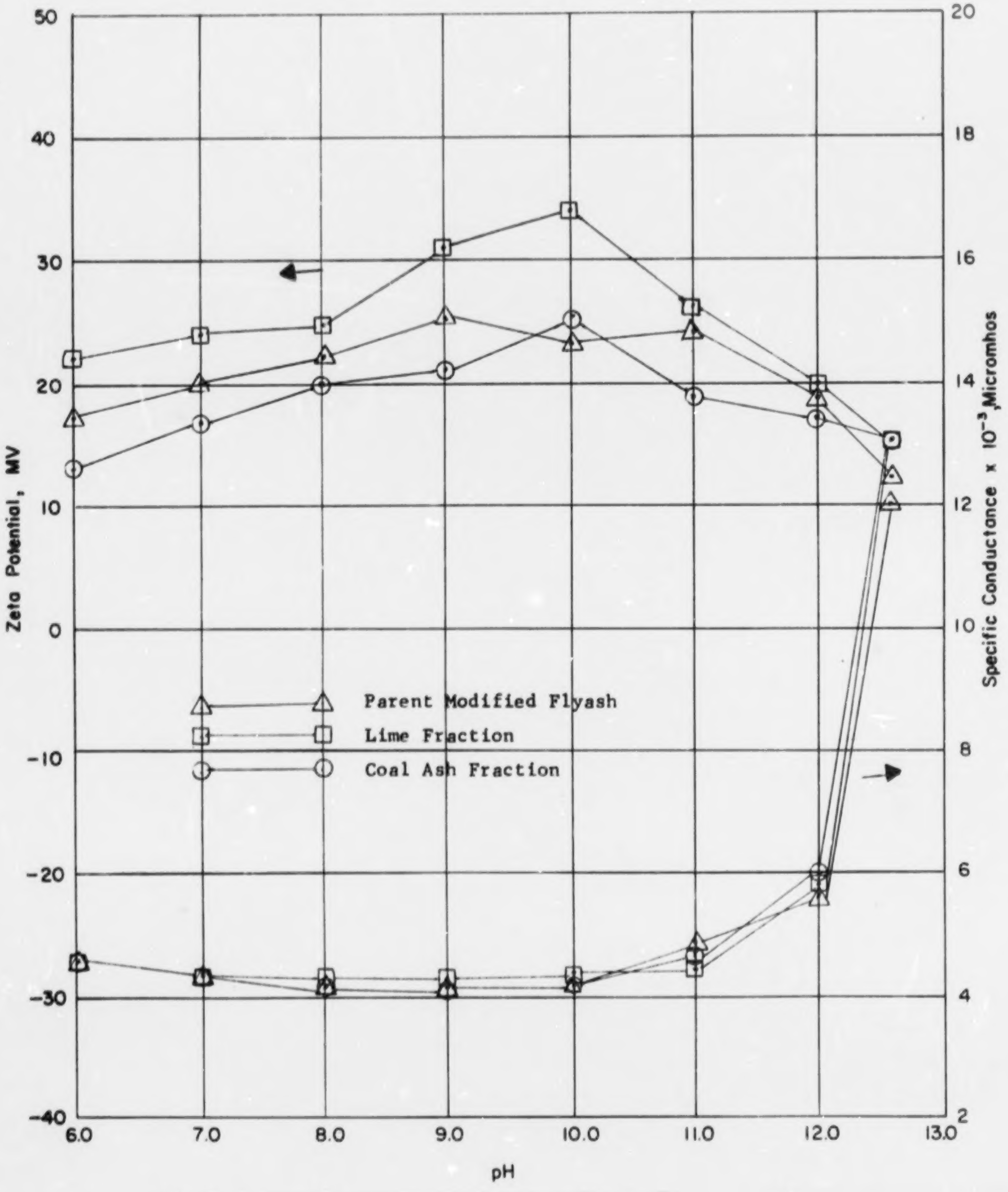


FIGURE 46B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 4.0 POUNDS PER TON OF TRIVALENT IRON AS FERRIC CHLORIDE TO A 33 PERCENT SLURRY CONCENTRATION

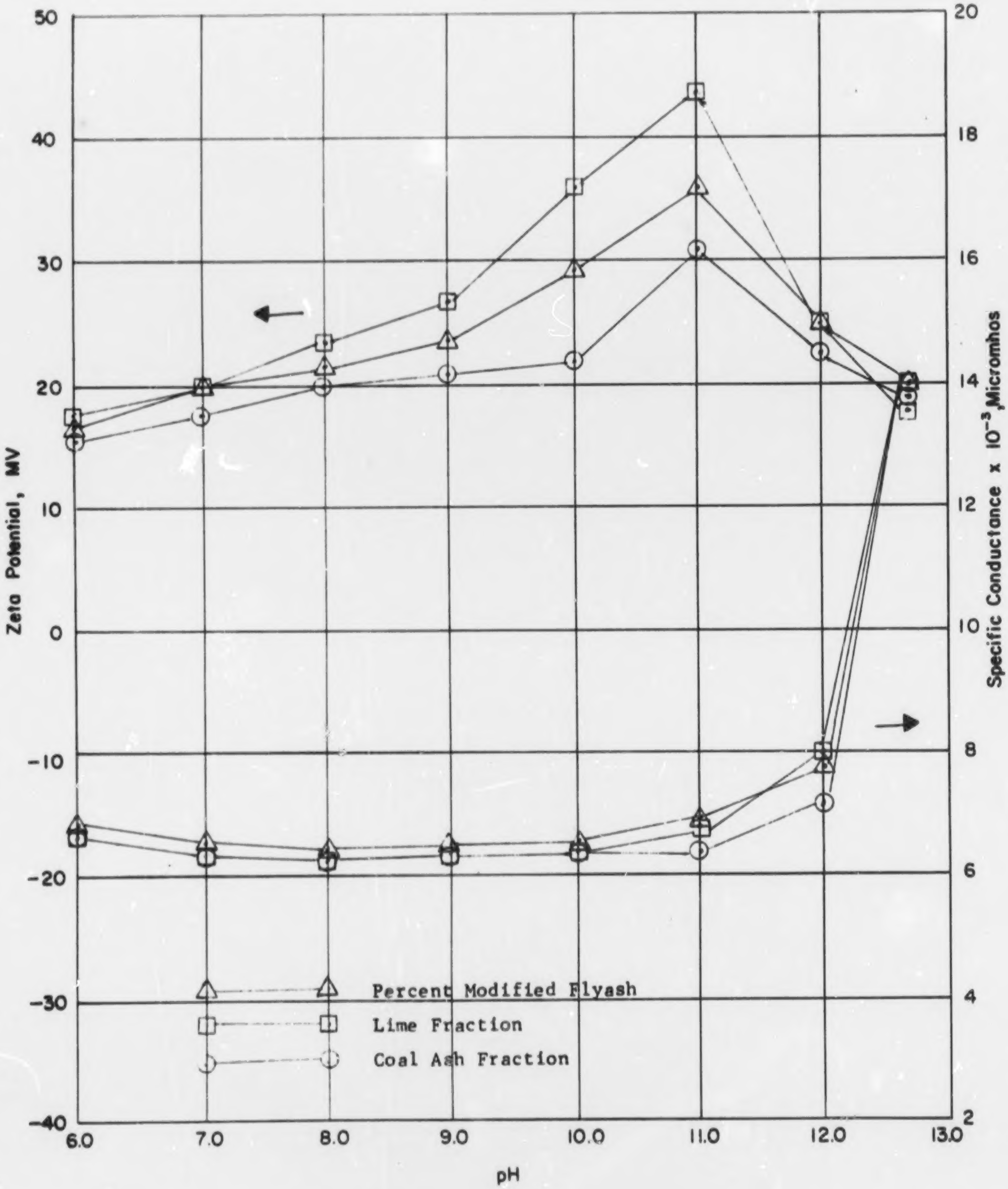


FIGURE 47B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 4.0 POUNDS PER TON OF TRIVALENT IRON AS FERRIC CHLORIDE TO A 16.5 PERCENT SLURRY CONCENTRATION

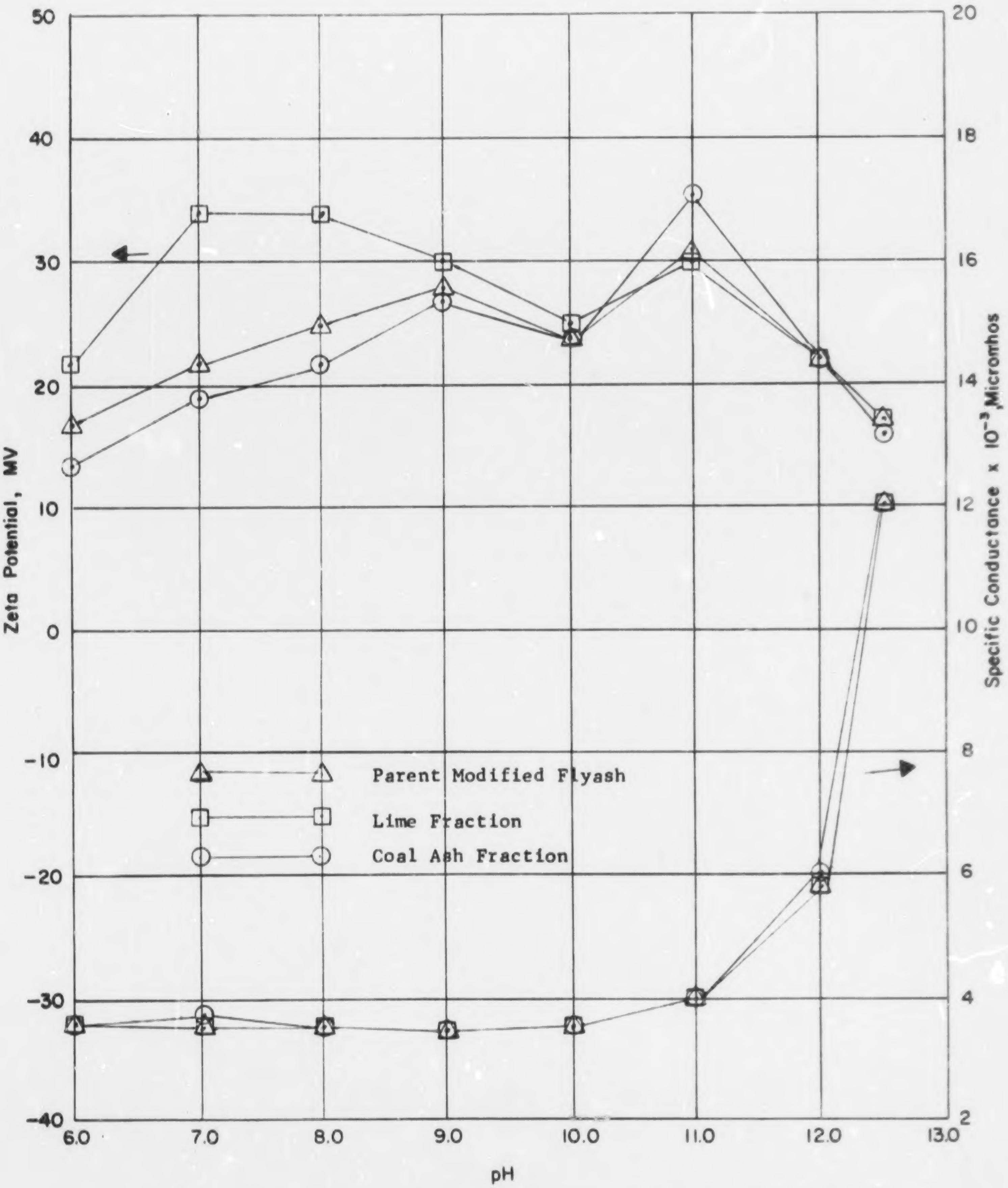


FIGURE 48B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 4.0 POUNDS PER TON OF TRIVALENT IRON AS FERRIC CHLORIDE TO A 8.25 PERCENT SLURRY CONCENTRATION

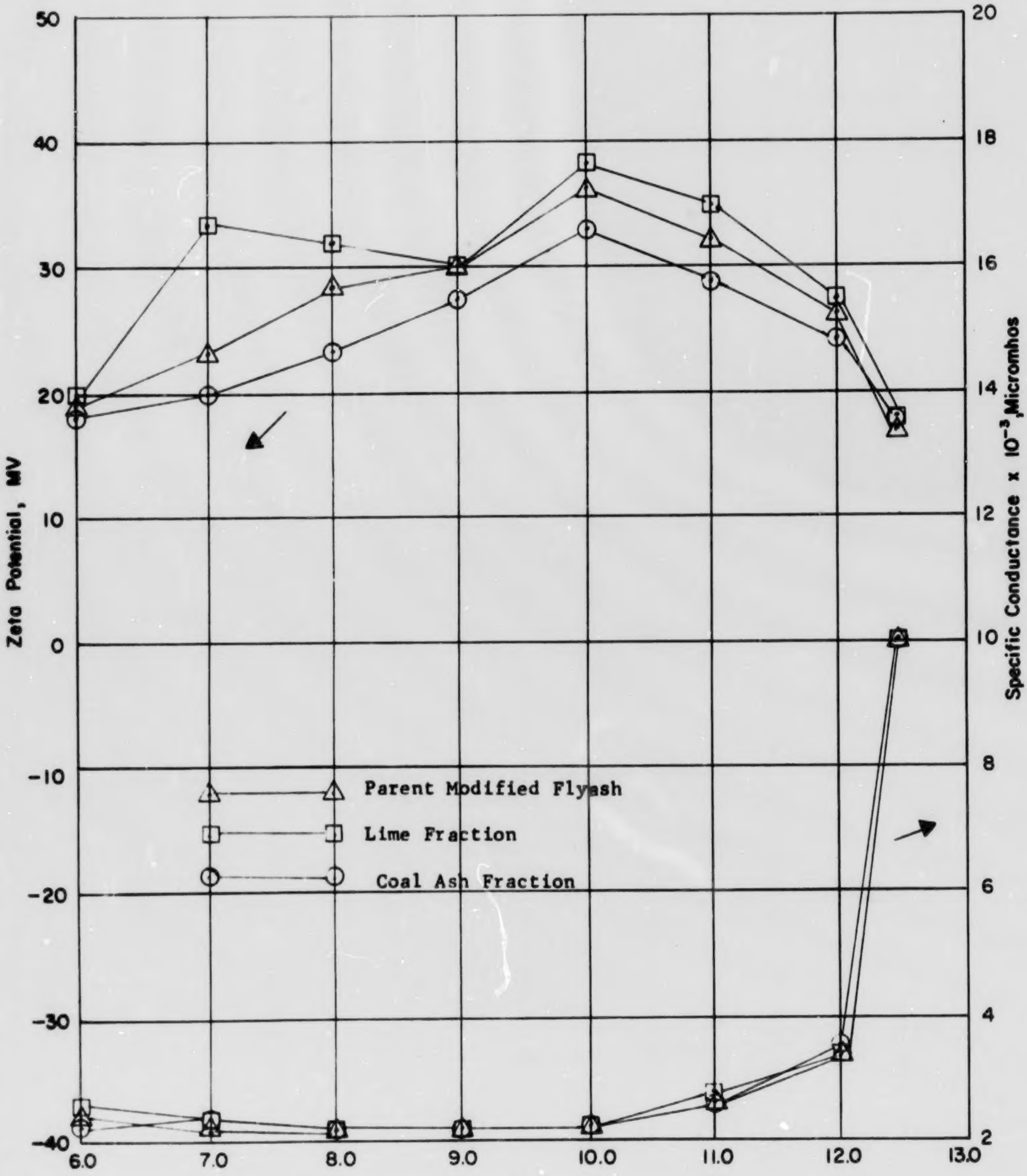


FIGURE 49B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 4.0 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM CHLORIDE TO A 33 PERCENT SLURRY CONCENTRATION

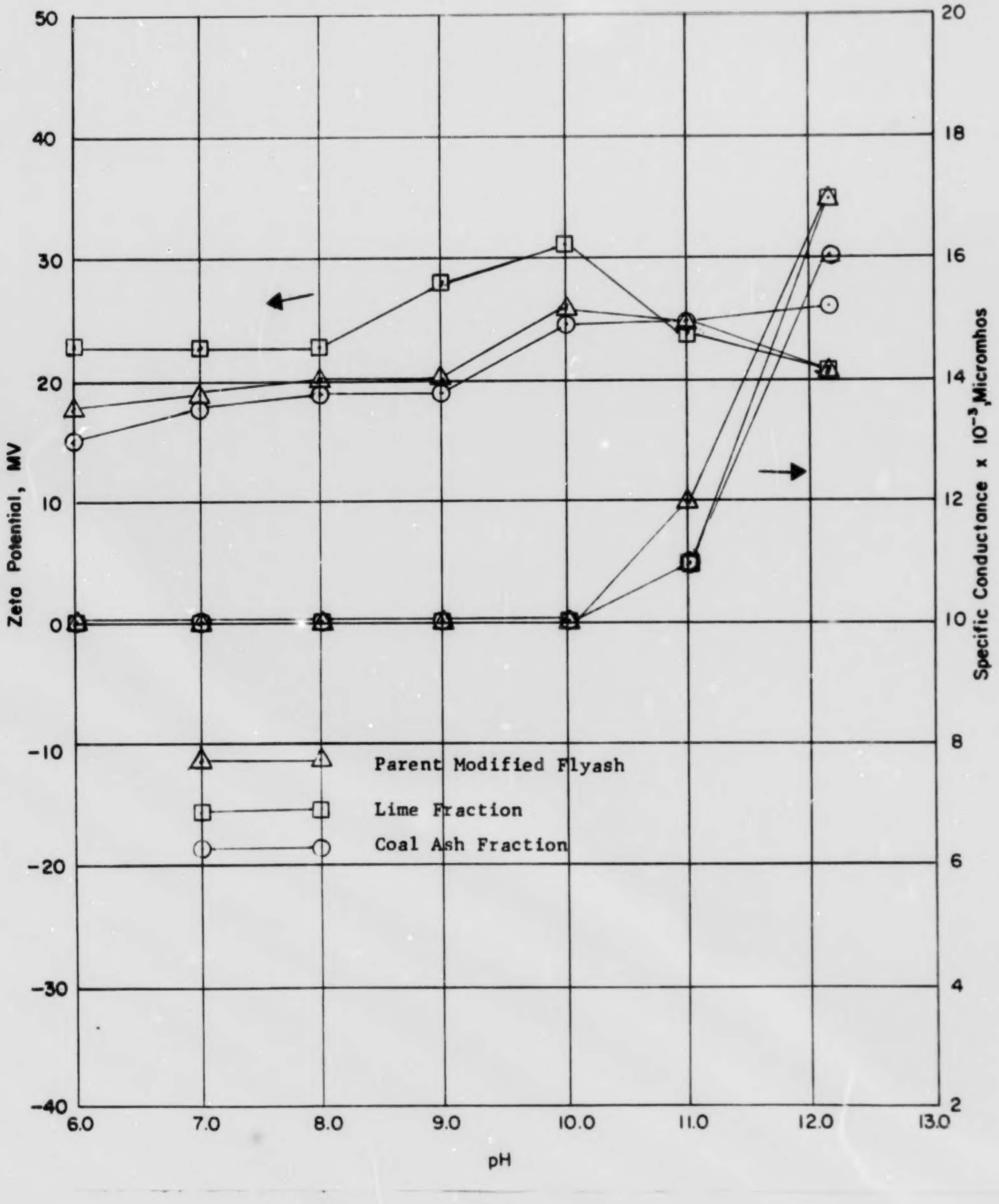


FIGURE 50B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 2.0 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM CHLORIDE TO A 33 PERCENT SLURRY CONCENTRATION

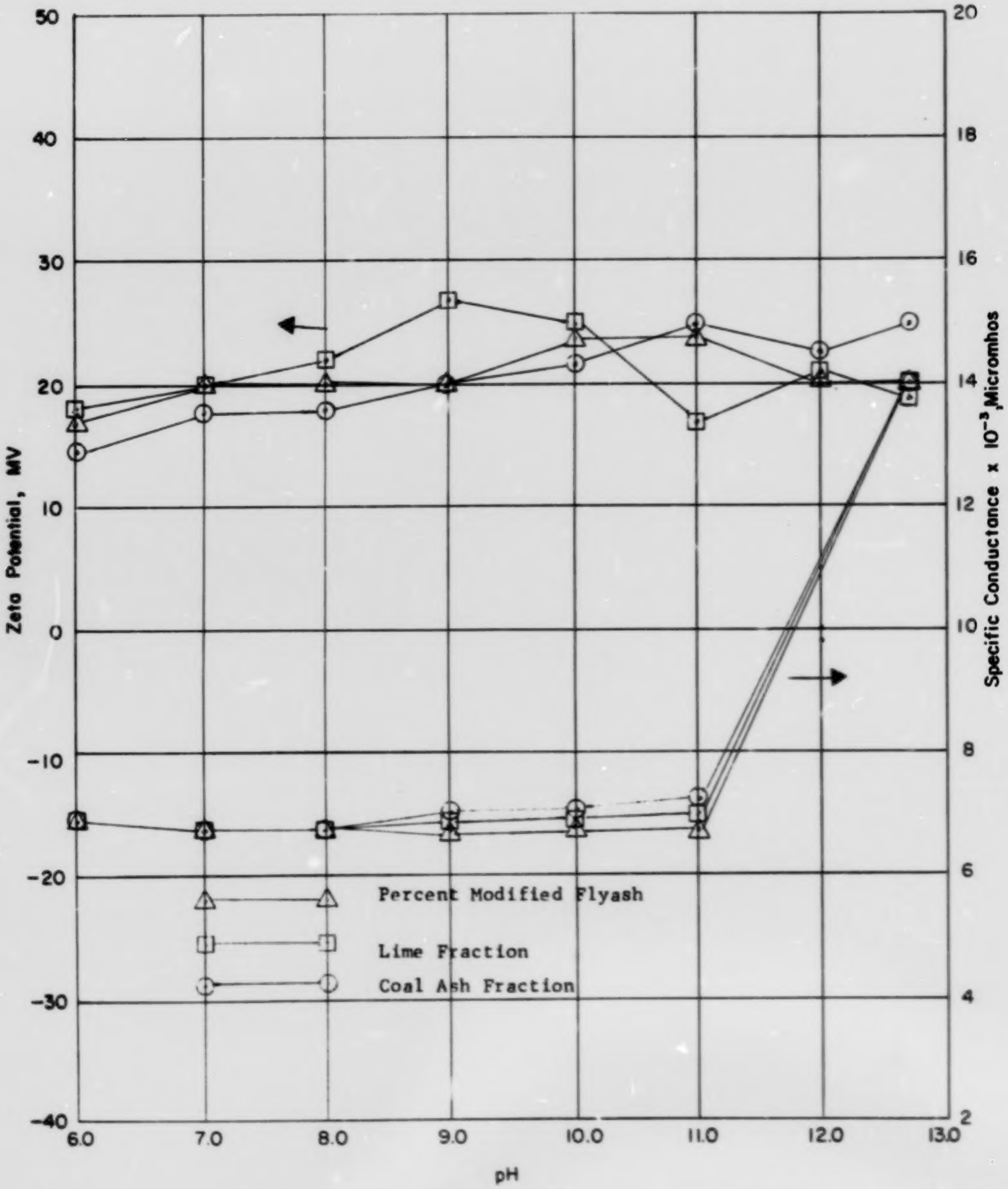


FIGURE 51B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1.0 POUND PER TON OF TRIVALENT ALUMINUM AS ALUMINUM CHLORIDE TO A 33 PERCENT SLURRY CONCENTRATION

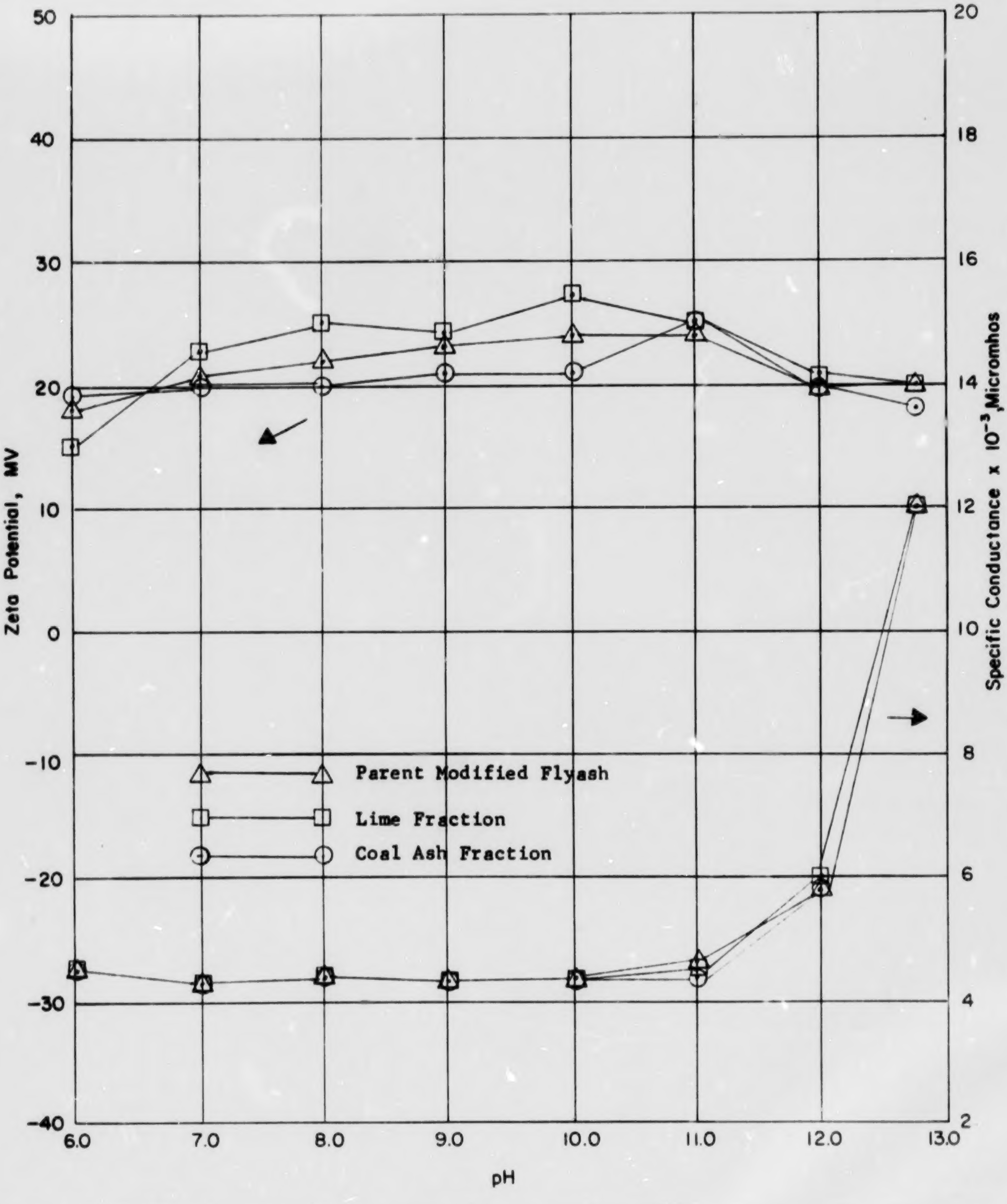


FIGURE 52B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.8 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM CHLORIDE TO A 33 PERCENT SLURRY CONCENTRATION

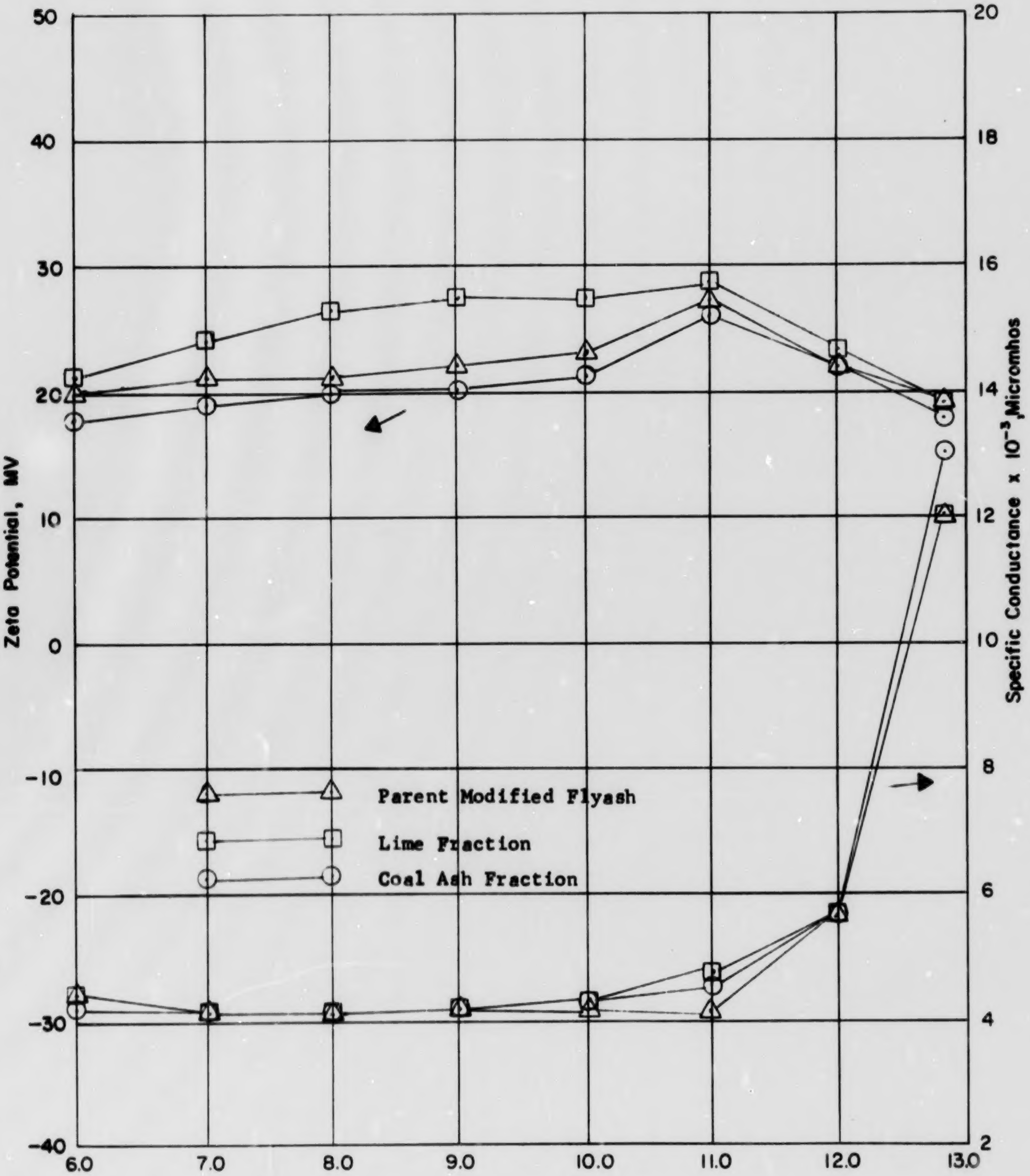


FIGURE 53B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.4 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM CHLORIDE TO A 33 PERCENT SLURRY CONCENTRATION

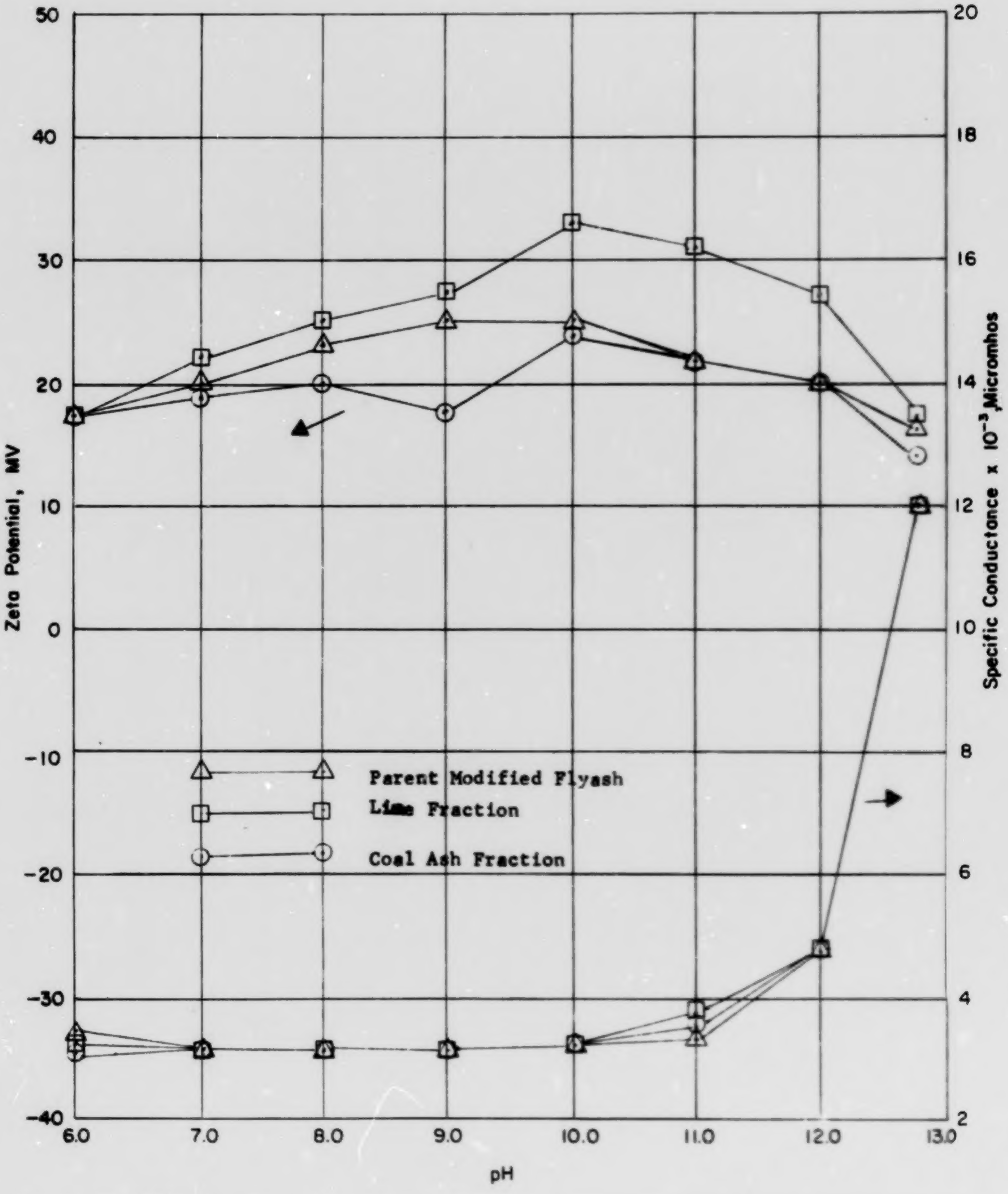


FIGURE 54B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.2 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM CHLORIDE TO A 33 PERCENT SLURRY CONCENTRATION

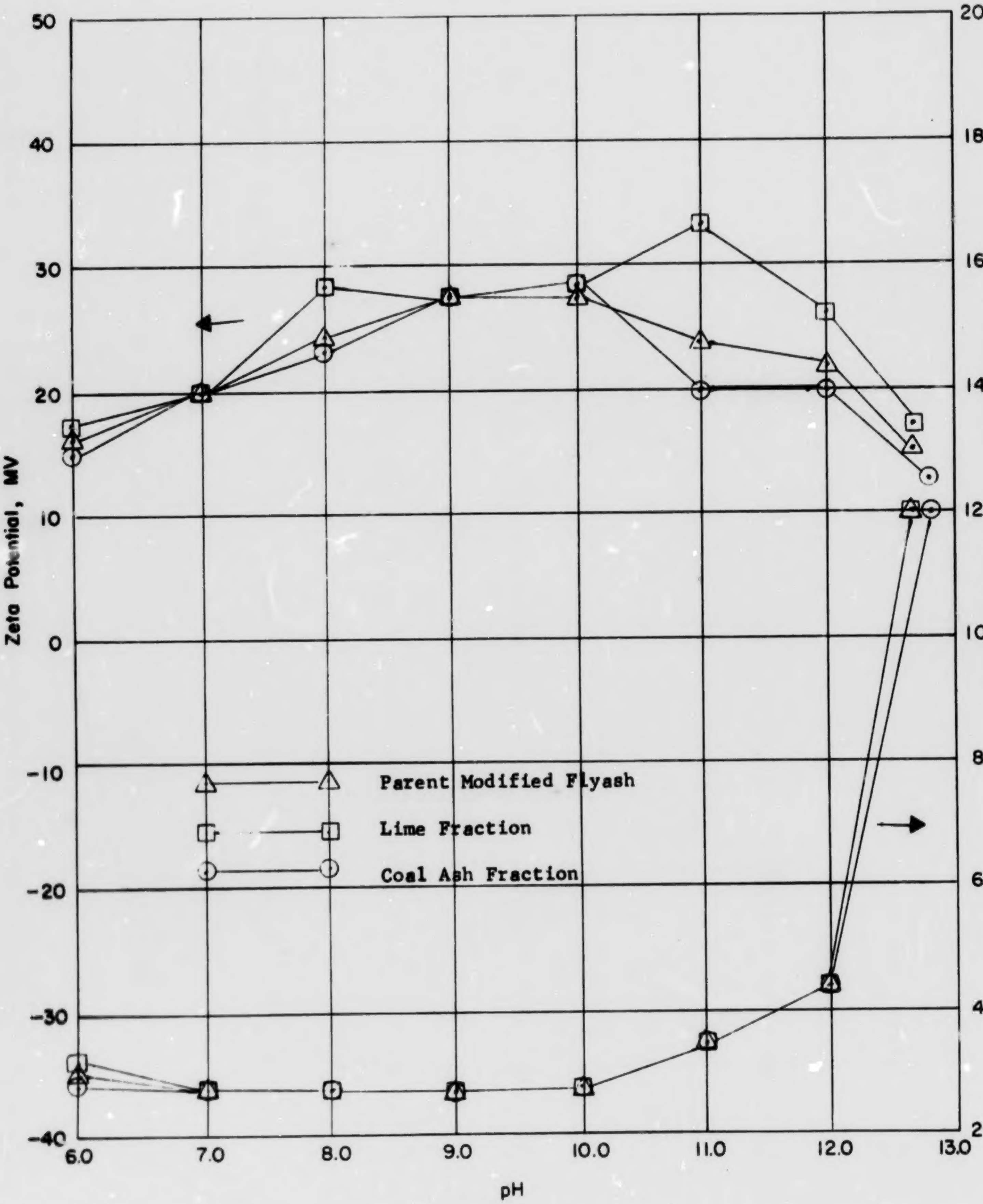


FIGURE 55B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.08 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM CHLORIDE TO A 33 PERCENT CONCENTRATION

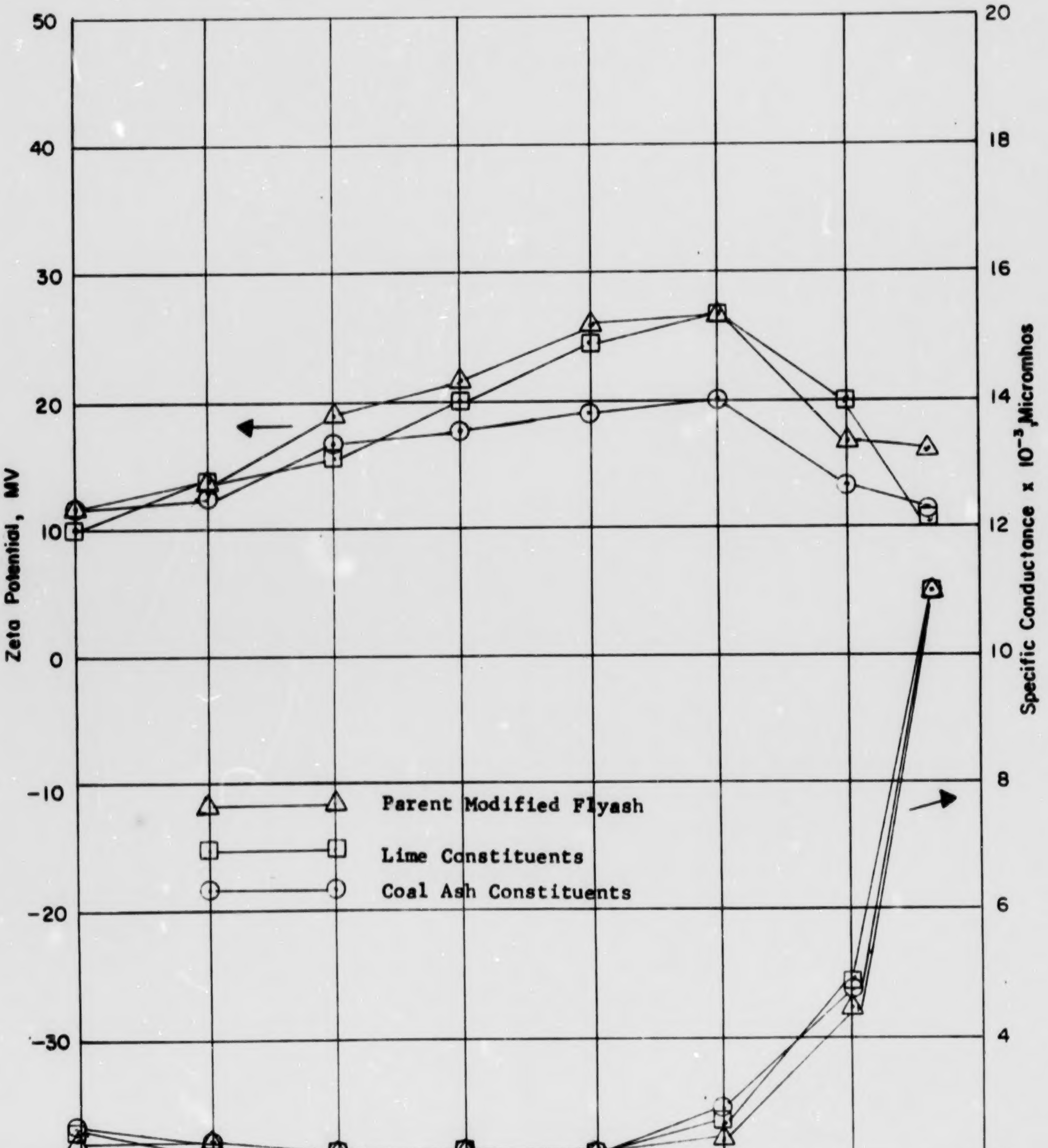


FIGURE 56B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF LIMESTONE MODIFIED FLYASH SAMPLE PID AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.04 POUNDS PER TON OF TRIVALENT ALUMINUM AS ALUMINUM CHLORIDE TO A 33 PERCENT CONCENTRATION

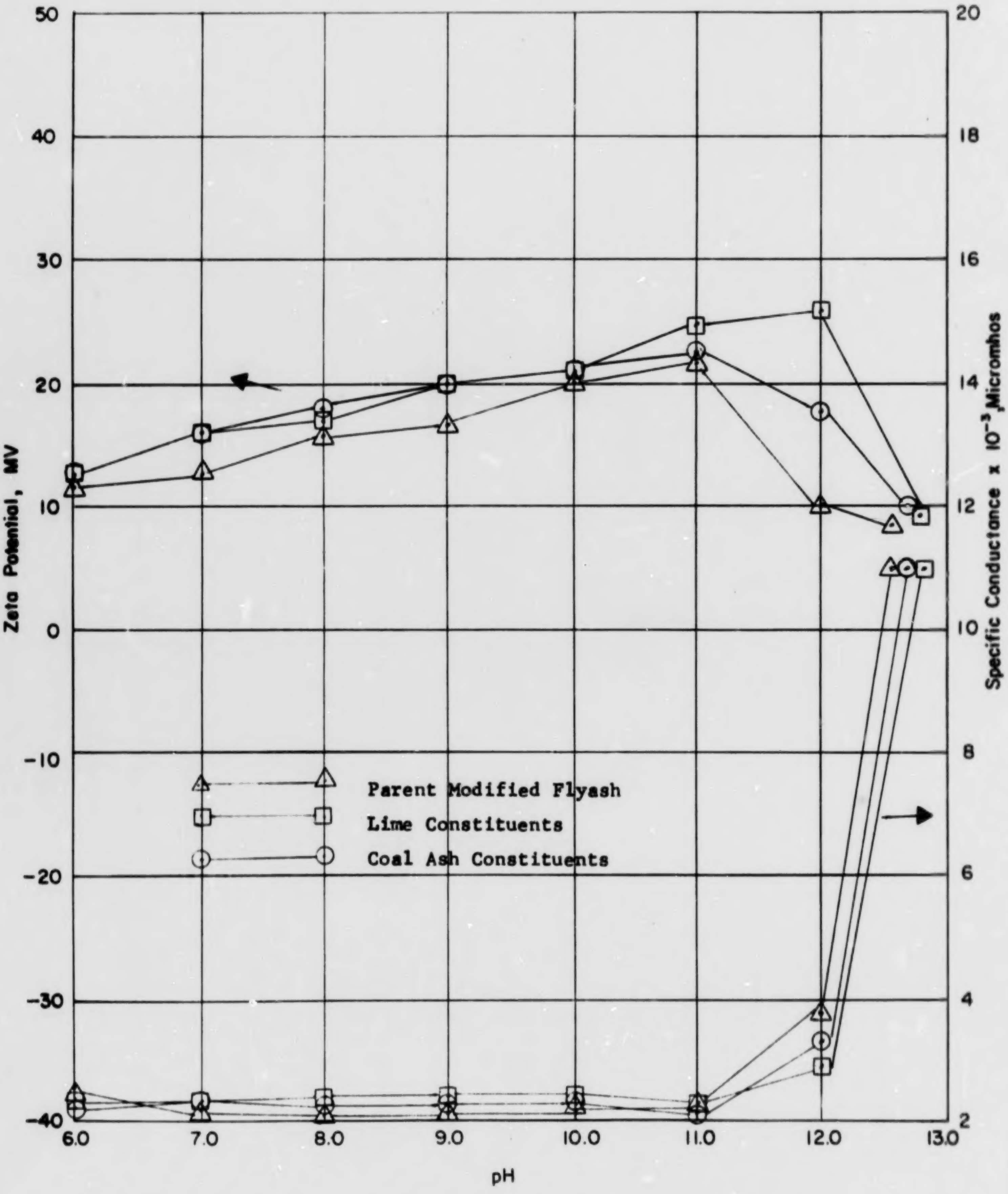


FIGURE 57B

THE EFFECT OF pH ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF 16.7 PERCENT SLURRIES OF UNMODIFIED CU AND DOLOMITE MODIFIED FLYASHES CI AND CU

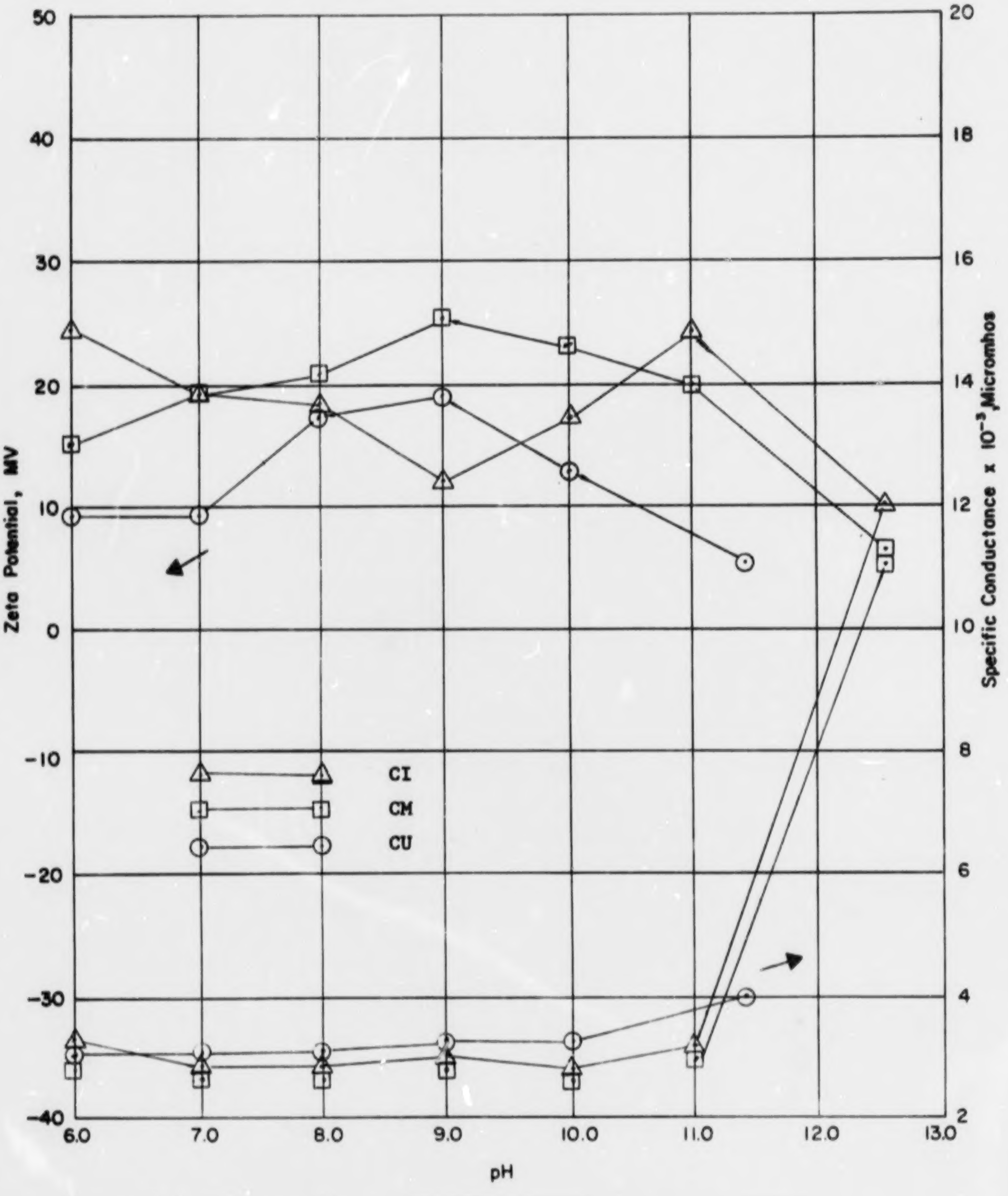


FIGURE 58B

THE EFFECT OF pH ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF A 16.70 PERCENT SLURRY OF DOLOMITE MODIFIED FLYASH CI AND THE COAL ASH CONSTITUENT OF CI

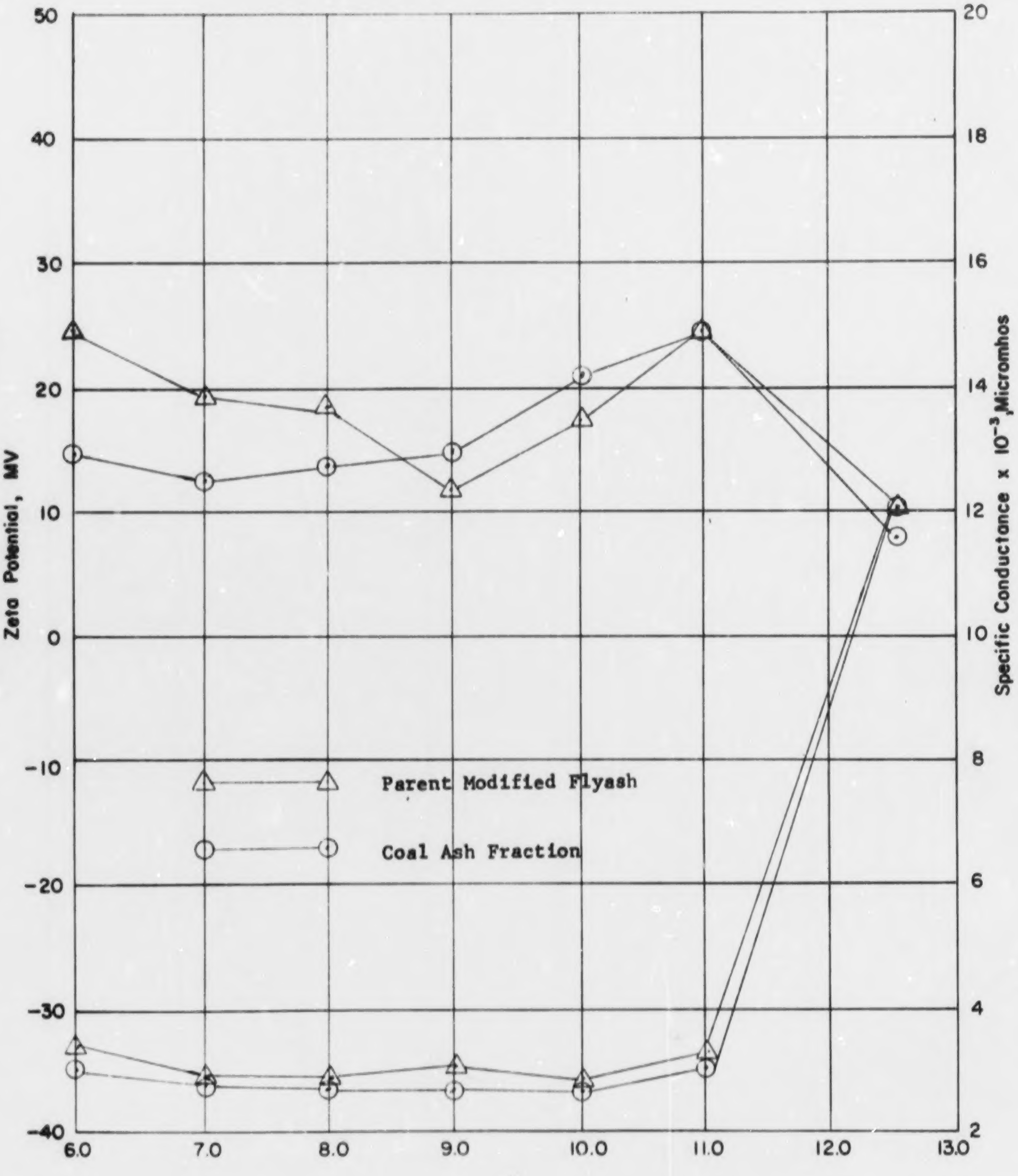


FIGURE 59B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE CONSTITUENTS OF DOLOMITE MODIFIED FLYASH SAMPLE CI AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1.0 POUNDS PER TON OF DIVALENT IRON AS FERROUS AMMONIUM SULFATE AT A 16.7 PERCENT SLURRY CONCENTRATION

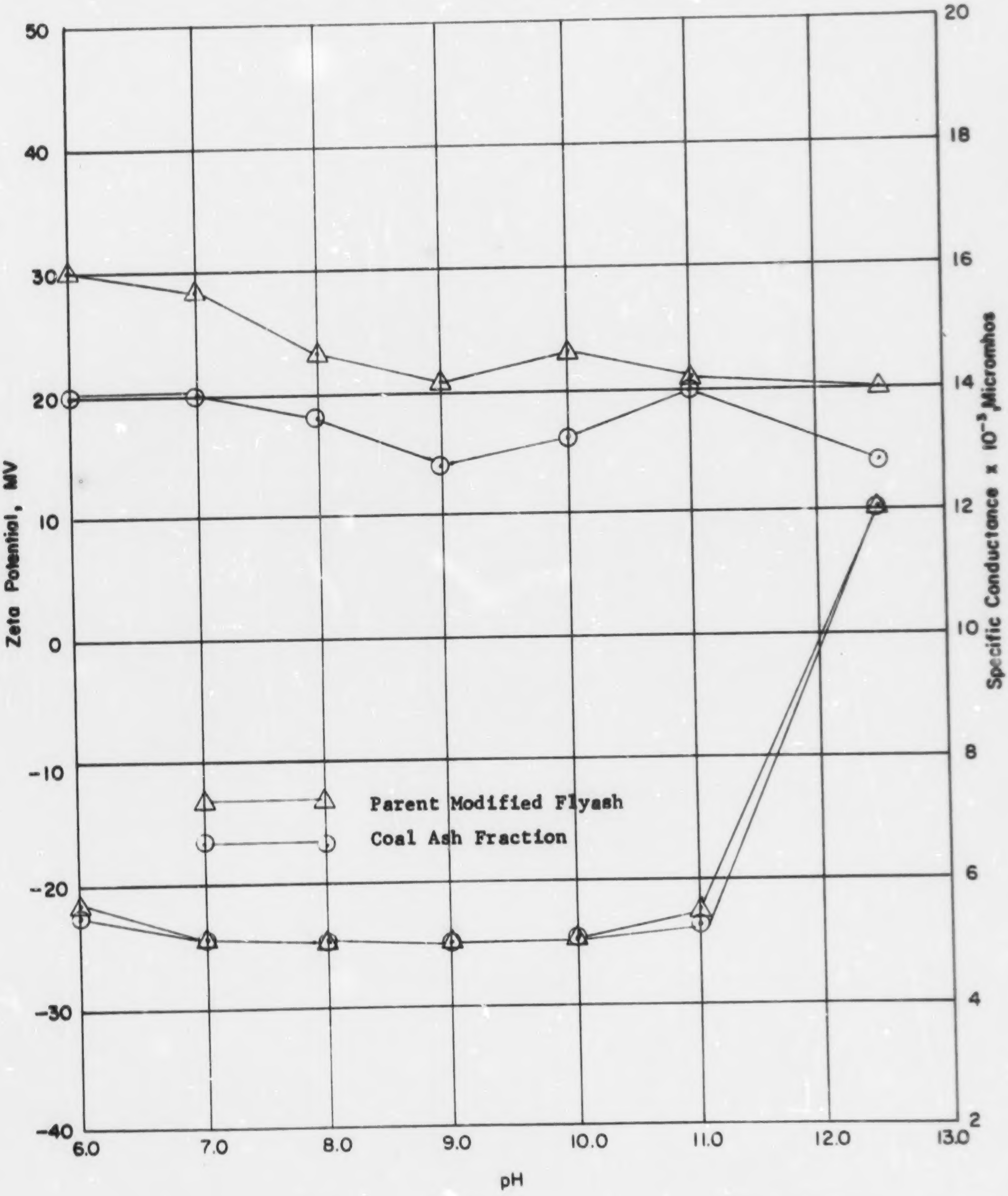


FIGURE 60B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE HEAD SAMPLE OF WET COLLECTED LIMESTONE MODIFIED FLYASH SAMPLE KPL AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1.0 POUND PER TON OF DIVALENT IRON AS FERROUS AMMONIUM SULFATE AT A 1.0 PERCENT SLURRY CONCENTRATION

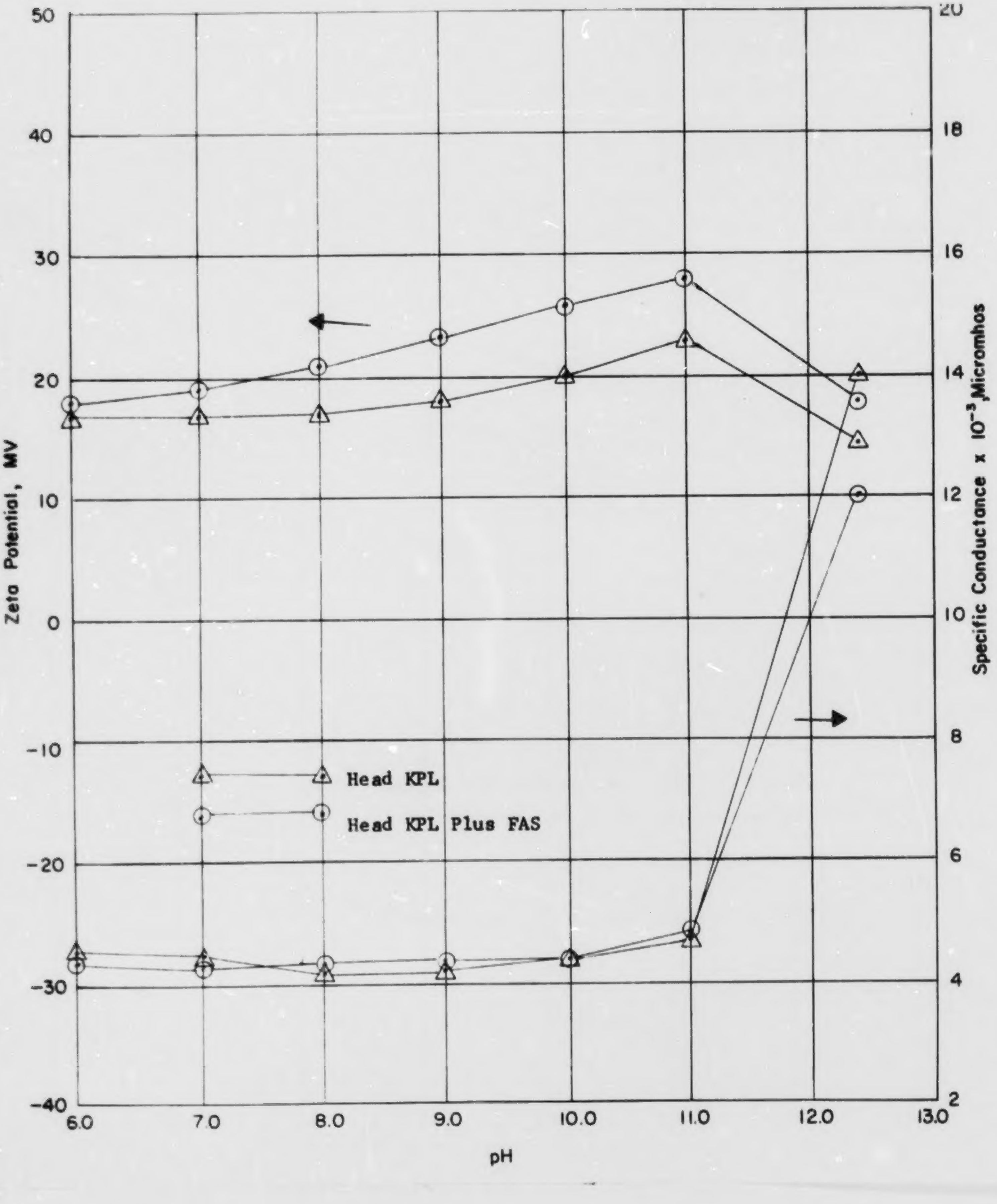


FIGURE 61B

THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE WITH CHANGES IN pH OF WET COLLECTED LIMESTONE MODIFIED FLYASH KPL, THE 3,000 GAUSS MAGNETIC FRACTION OF KPL AND THE 3,000 GAUSS NONMAGNETIC FRACTION OF KPL IN LIQUORS CONTAINING THE SOLUBLE CONSTITUENTS OF KPL AT A 1.0 PERCENT SLURRY CONCENTRATION

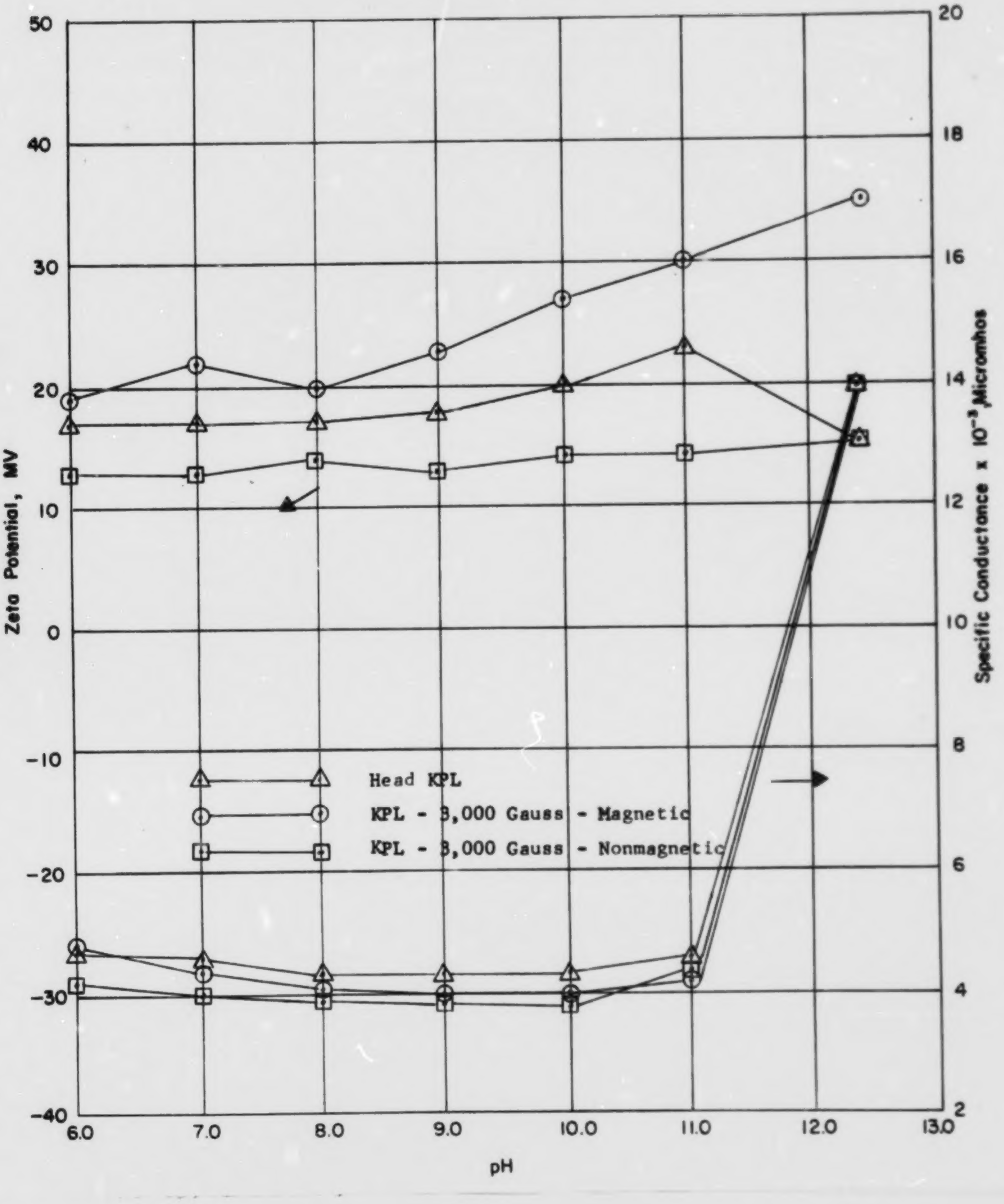


FIGURE 62B

THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE WITH CHANGES IN pH OF WET COLLECTED LIMESTONE MODIFIED FLYASH KPL, THE 5,500 GAUSS MAGNETIC FRACTION OF KPL AND THE 5,500 GAUSS NONMAGNETIC FRACTION OF KPL IN LIQUORS CONTAINING THE SOLUBLE CONSTITUENTS OF KPL AT A 1.0 PERCENT SLURRY CONCENTRATION

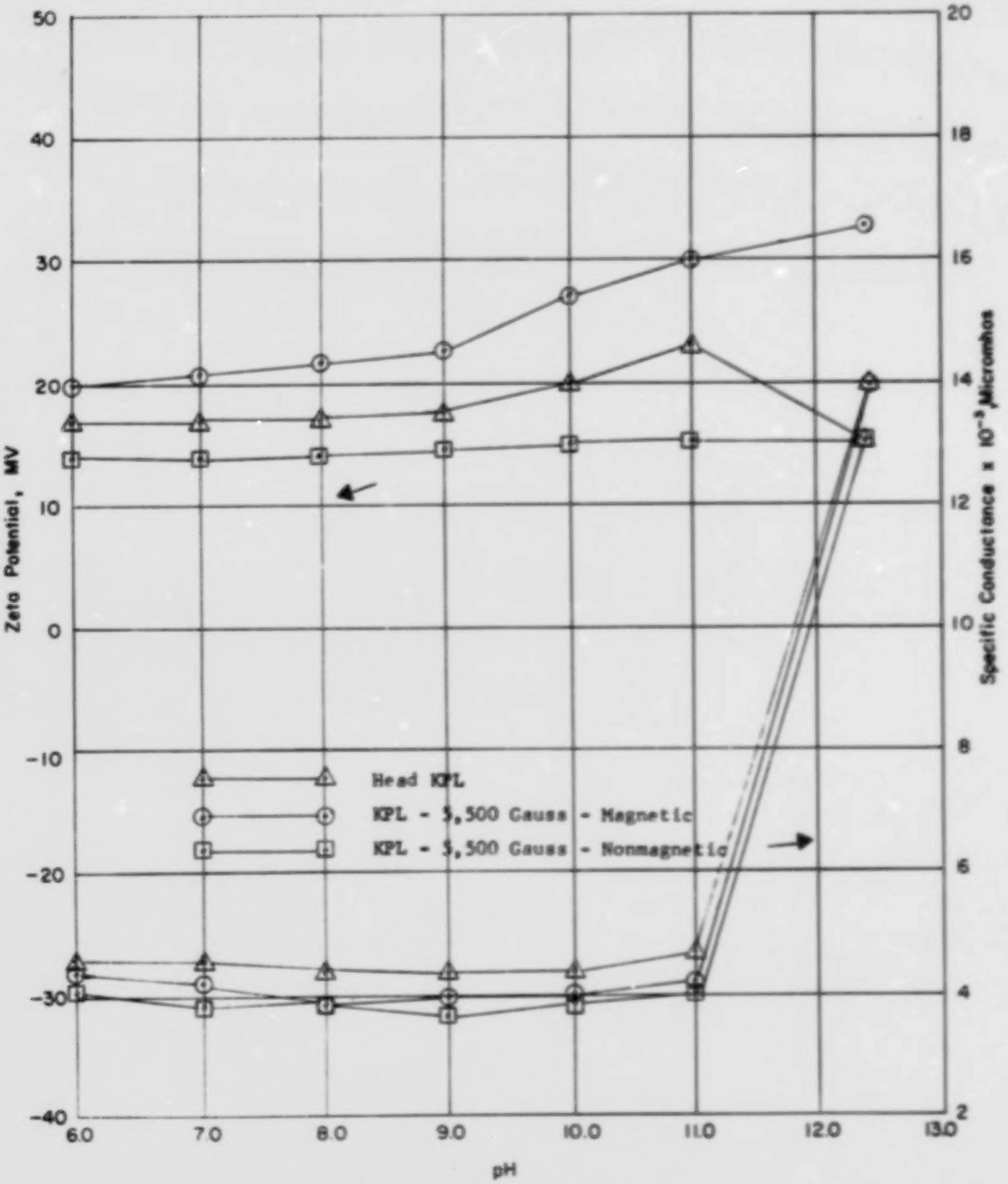


FIGURE 63B

THE EFFECT ON THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE HEAD SAMPLE OF WET COLLECTED DOLOMITE MODIFIED FLYASH SAMPLE SLD AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1.0 POUND PER TON OF DIVALENT IRON AS FERROUS AMMONIUM SULFATE TO A 2.0 PERCENT SLURRY CONCENTRATION

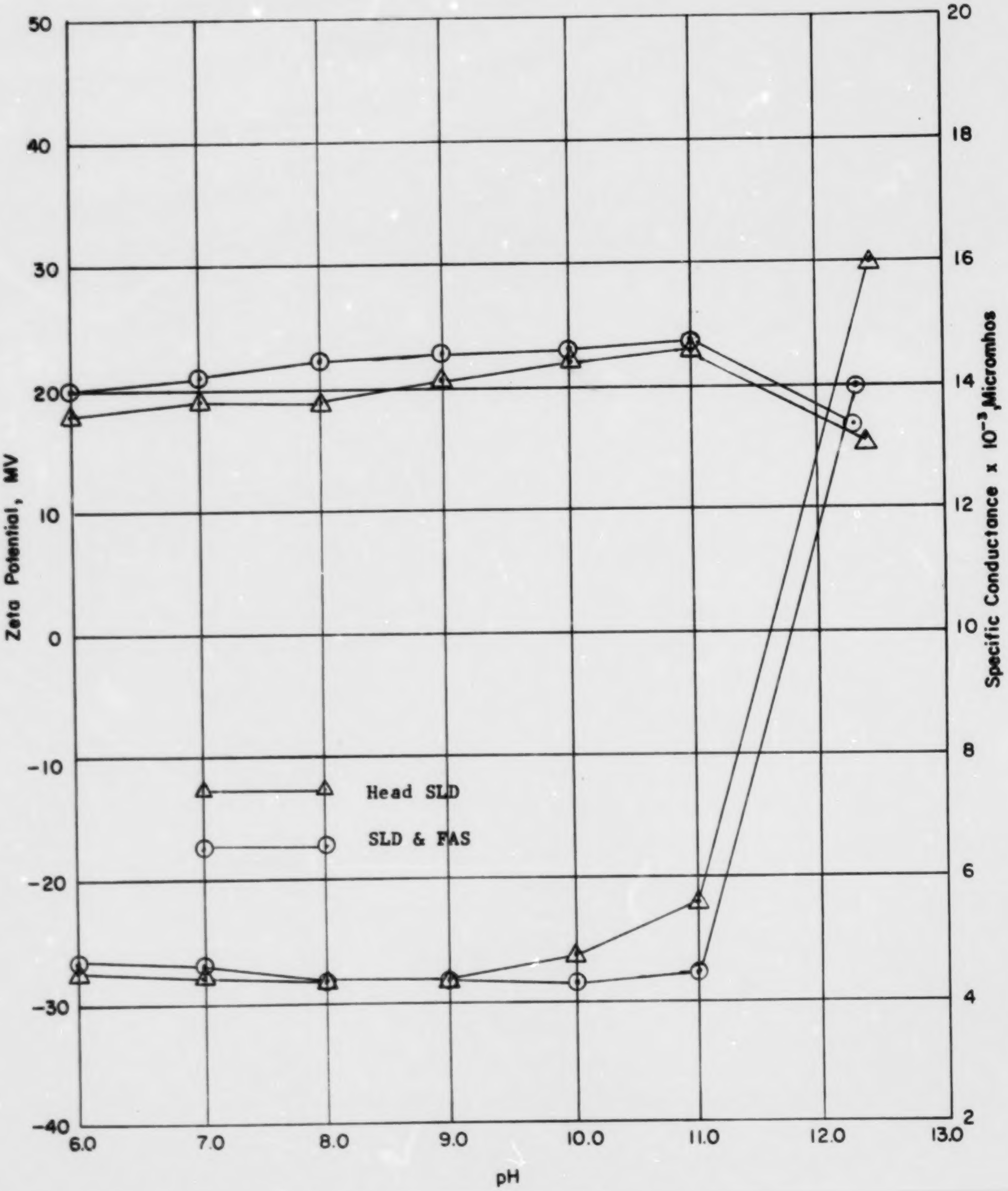


FIGURE 64B

THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE WITH CHANGES IN pH OF WET COLLECTED DOLOMITE MODIFIED FLYASH SLD, 3,000 GAUSS MAGNETIC FRACTION OF SLD AND THE 3,000 GAUSS NONMAGNETIC FRACTION OF SLD AT A 2.0 PERCENT SLURRY CONCENTRATION

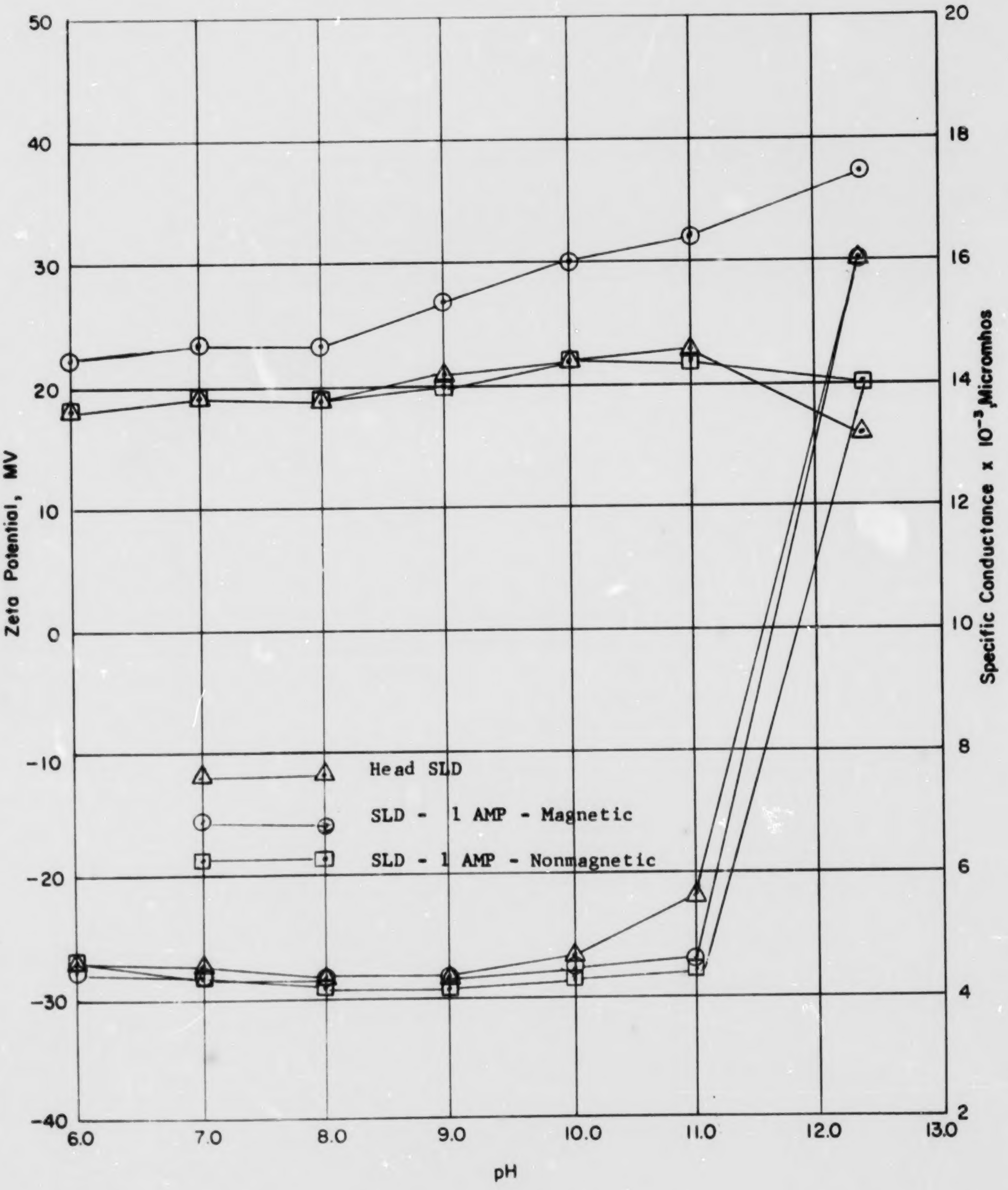


FIGURE 65B

THE ZETA POTENTIAL AND SPECIFIC CONDUCTANCE WITH CHANGES IN pH OF WET COLLECTED DOLOMITE MODIFIED FLYASH SLD, THE 5,500 GAUSS MAGNETIC FRACTION OF SLD AND THE 5,500 GAUSS NONMAGNETIC FRACTION OF SLD AT A 2.0 PERCENT SLURRY CONCENTRATION

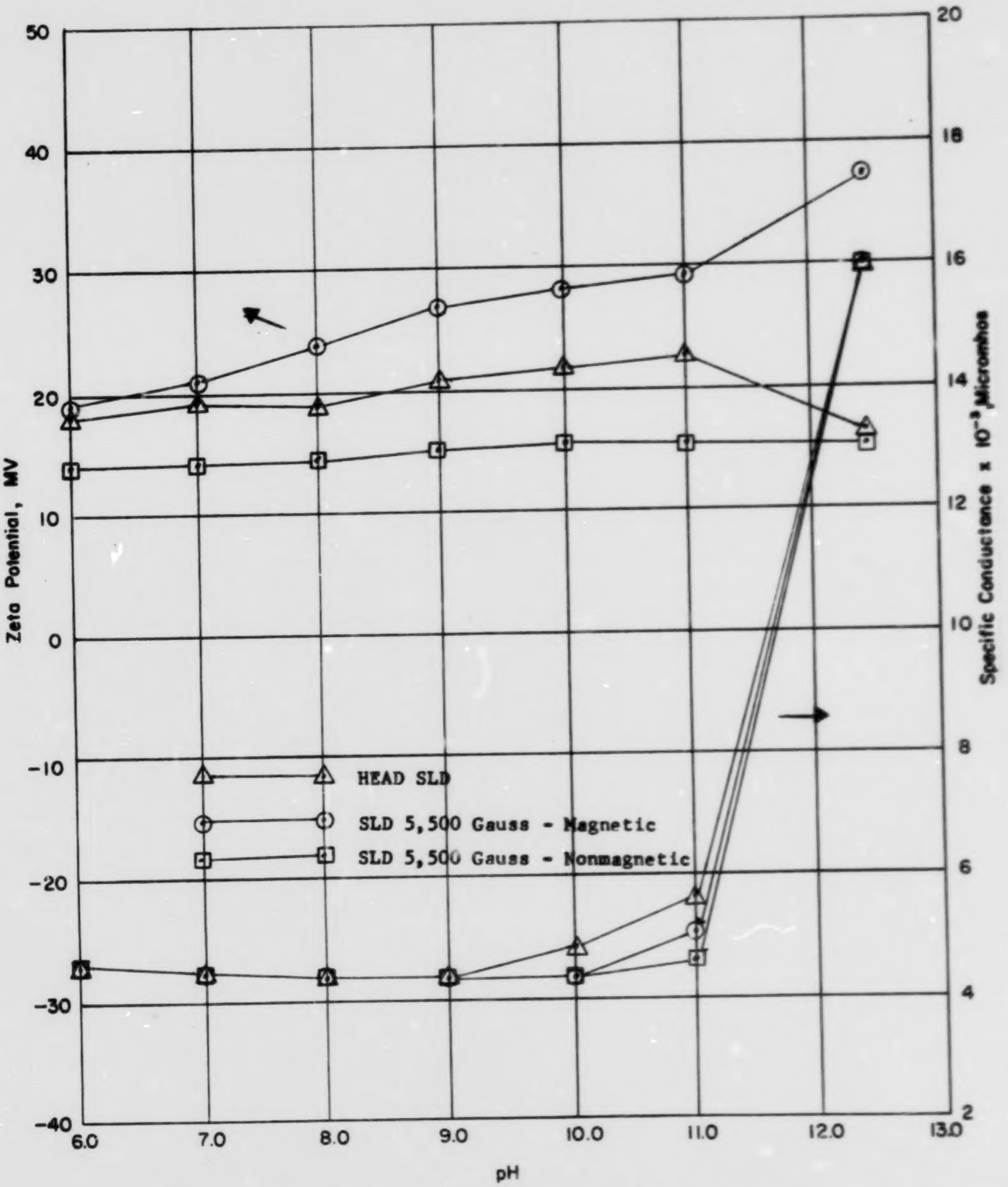


FIGURE 66B

ZETA POTENTIAL AND SPECIFIC CONDUCTANCE WITH CHANGES IN pH OF WET COLLECTED LIMESTONE MODIFIED FLYASH KPL, THE 3,000 MAGNETIC FRACTION AND THE 3,000 GAUSS NONMAGNETIC FRACTION OF KPL AT A 1.0 PERCENT SLURRY CONCENTRATION

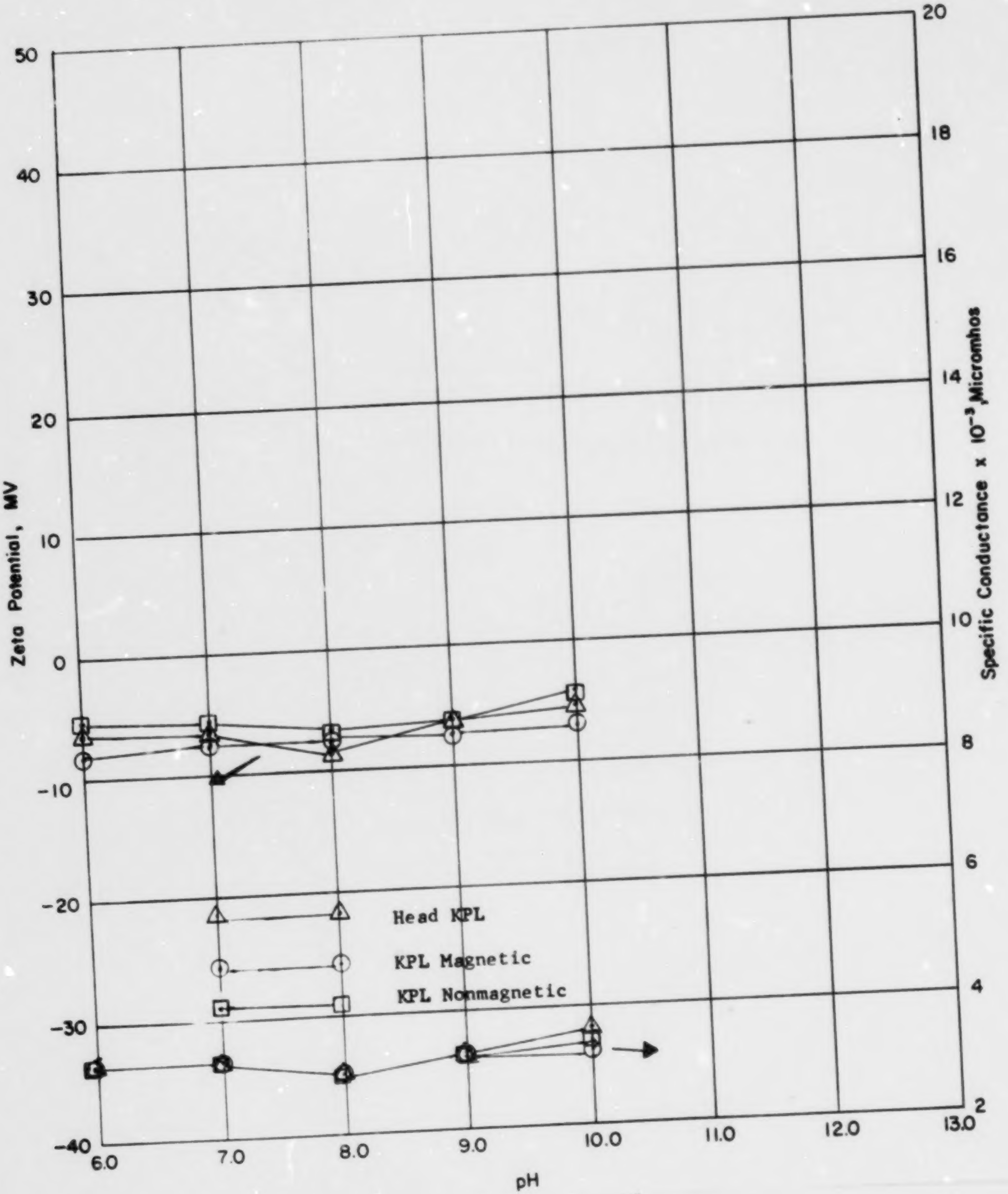


FIGURE 67B

THE EFFECT ON ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE HEAD, 3,000 GAUSS MAGNETIC AND 3,000 GAUSS NONMAGNETIC SAMPLES OF WET COLLECTED LIMESTONE MODIFIED FLYASH SAMPLE KPL AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 2 POUNDS PER TON OF DIVALENT IRON AS FERROUS AMMONIUM SULFATE AT A 1.0 SLURRY CONCENTRATION

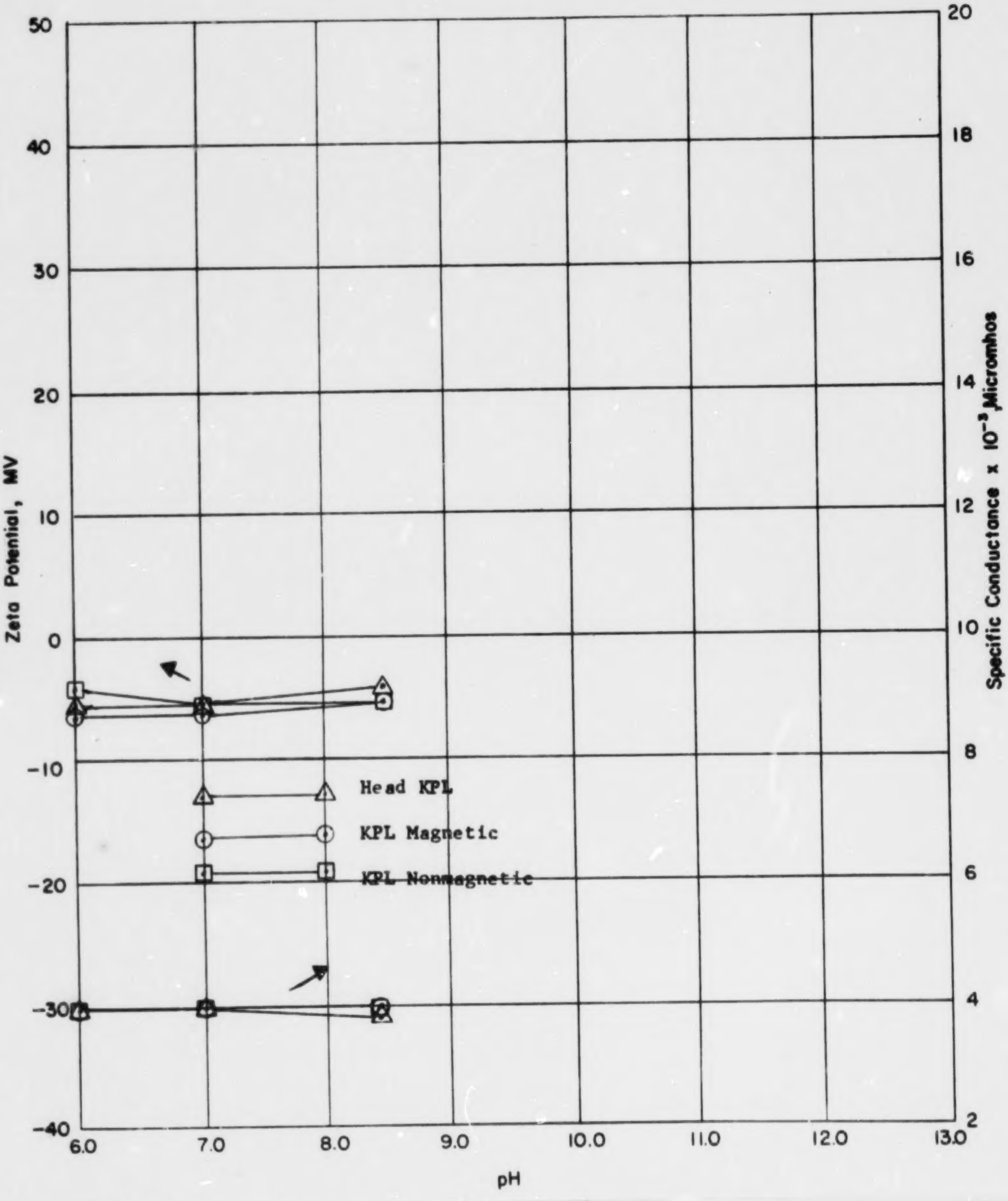


FIGURE 68B

THE EFFECT ON ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE HEAD, 3,000 GAUSS MAGNETIC AND 3,000 GAUSS NONMAGNETIC SAMPLES OF WET COLLECTED LIMESTONE MODIFIED FLYASH SAMPLE KPL AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 0.5 POUNDS PER TON OF DIVALENT SULFUR AS SODIUM SULFIDE AT A 1.0 PERCENT SLURRY CONCENTRATION

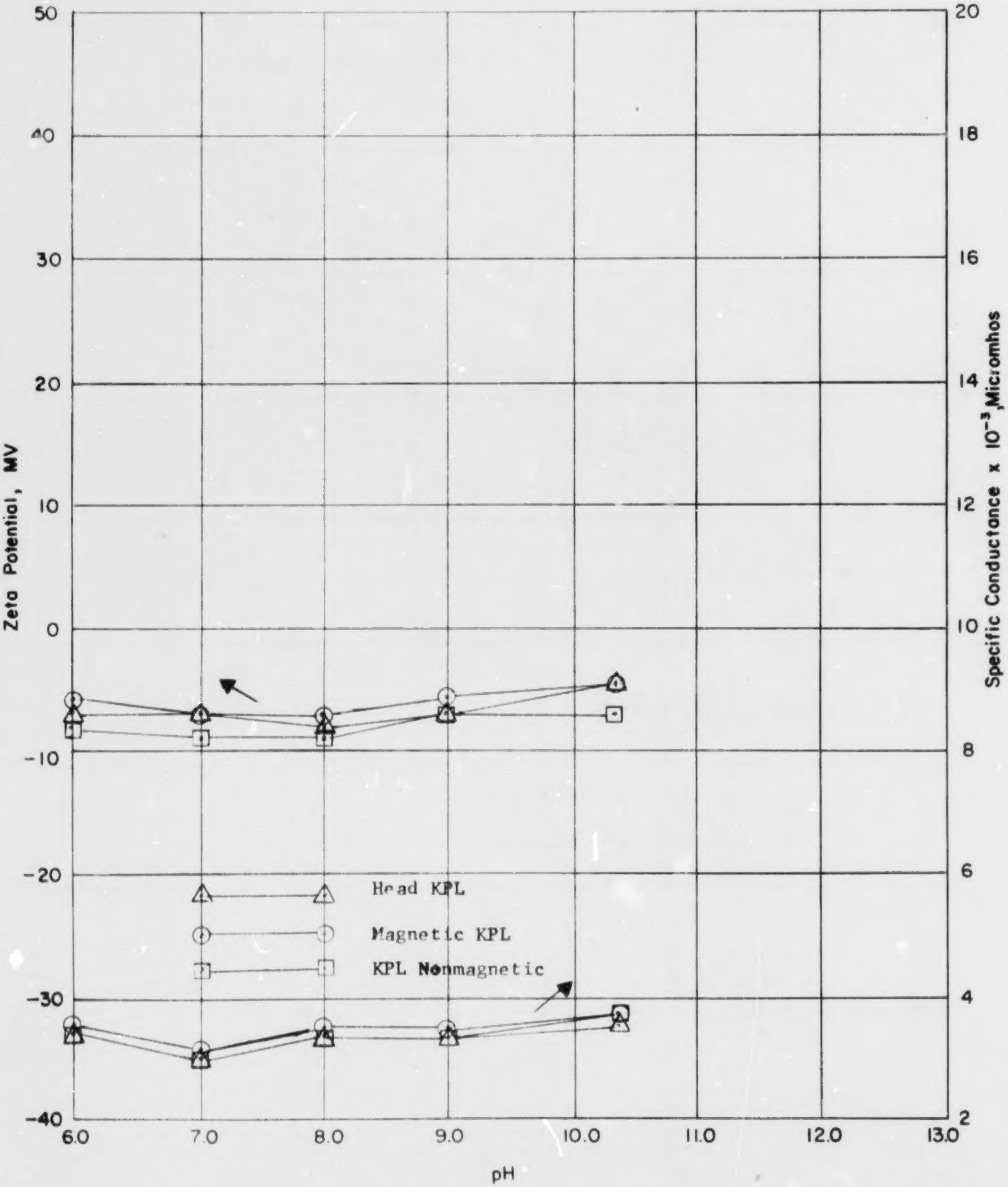


FIGURE 69B

THE EFFECT ON ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE HEAD, 3,000 GAUSS MAGNETIC AND 3,000 GAUSS NONMAGNETIC SAMPLES OF WET COLLECTED LIMESTONE MODIFIED FLYASH SAMPLE KPL AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1 POUND PER TON OF DIVALENT SULFUR AS SODIUM SULFIDE AT A 1.0 PERCENT SLURRY CONCENTRATION

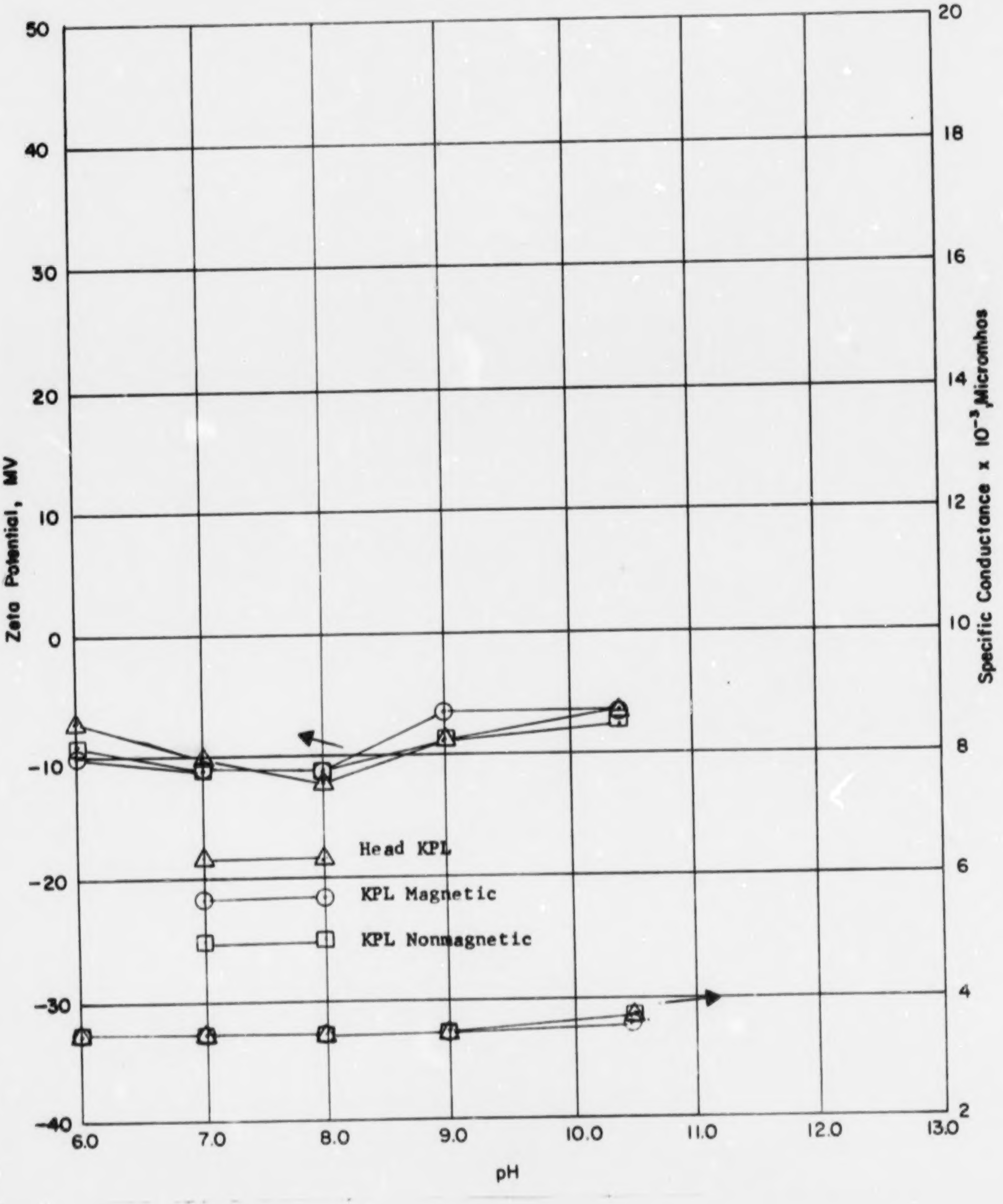


FIGURE 70B

THE EFFECT ON ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE HEAD, 3,000 GAUSS MAGNETIC AND 3,000 GAUSS NONMAGNETIC SAMPLES OF WET COLLECTED LIMESTONE MODIFIED FLYASH SAMPLE KPL AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 2 POUNDS PER TON OF DIVALENT SULFUR AS SODIUM SULFIDE AT A 1.0 PERCENT SLURRY CONCENTRATION

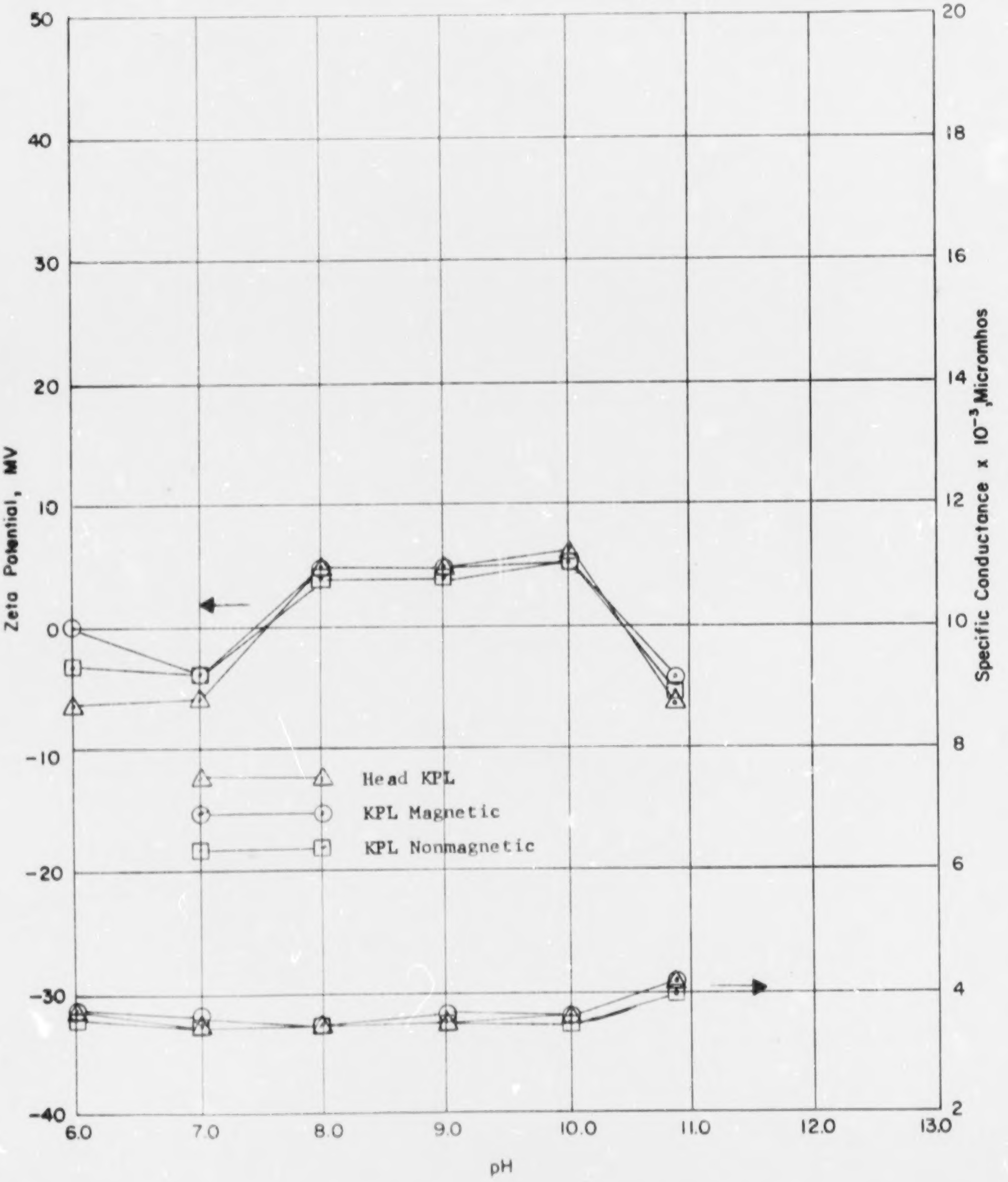


FIGURE 71B

THE EFFECT ON ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE HEAD, 3,000 GAUSS MAGNETIC AND 3,000 GAUSS NONMAGNETIC SAMPLES OF WET COLLECTED LIMESTONE MODIFIED FLYASH SAMPLE KPL AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 4 POUNDS PER TON OF DIVALENT SULFUR AS SODIUM SULFIDE AT A 1.0 PERCENT SLURRY CONCENTRATION

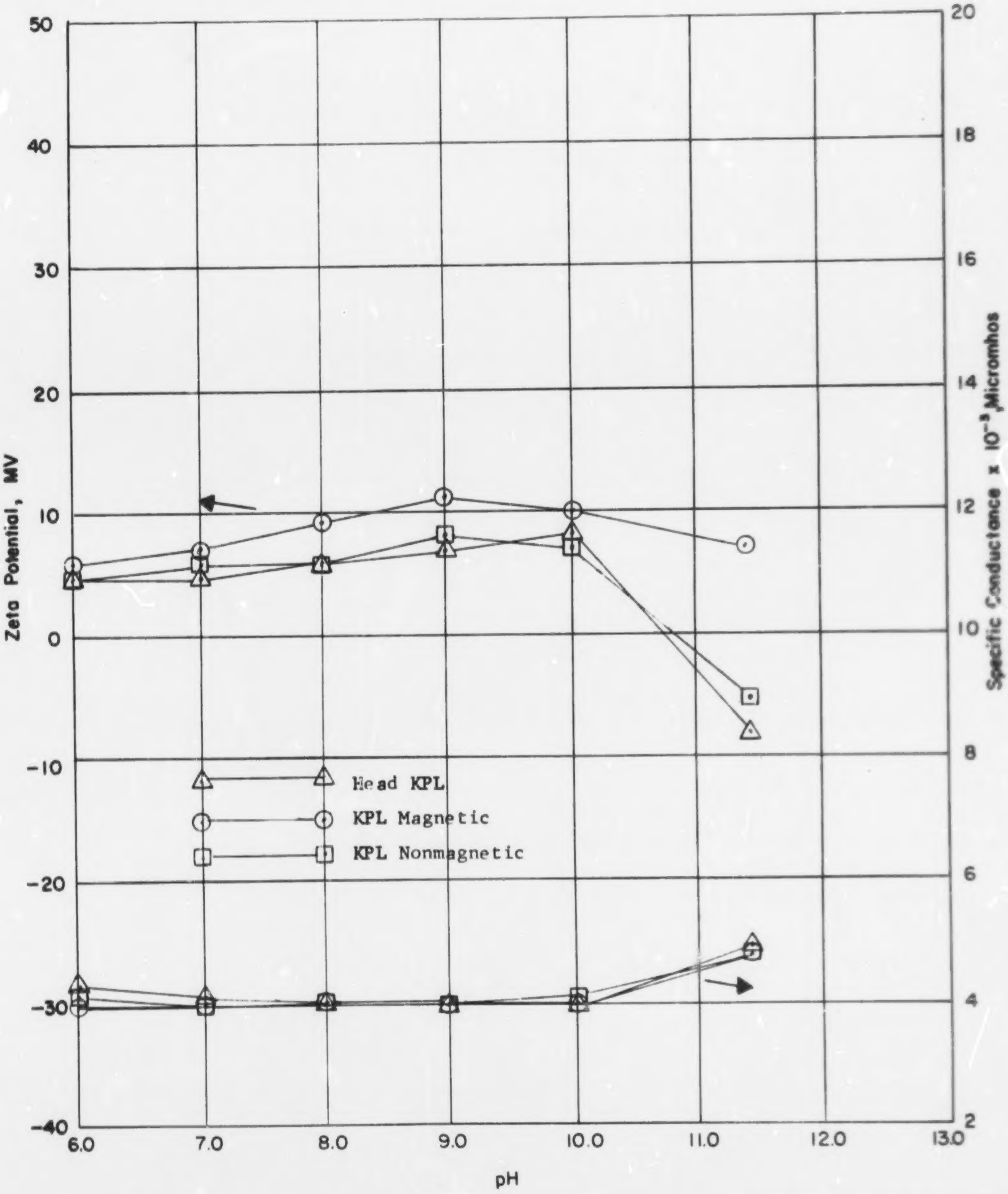


FIGURE 72B

THE EFFECT ON ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE HEAD, 3,000 GAUSS MAGNETIC AND 3,000 GAUSS NONMAGNETIC SAMPLES OF WET COLLECTED LIMESTONE MODIFIED FLYASH SAMPLE KPL AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 10 POUNDS PER TON OF DIVALENT SULFUR AS SODIUM SULFIDE AT A 1.0 PERCENT SLURRY CONCENTRATION

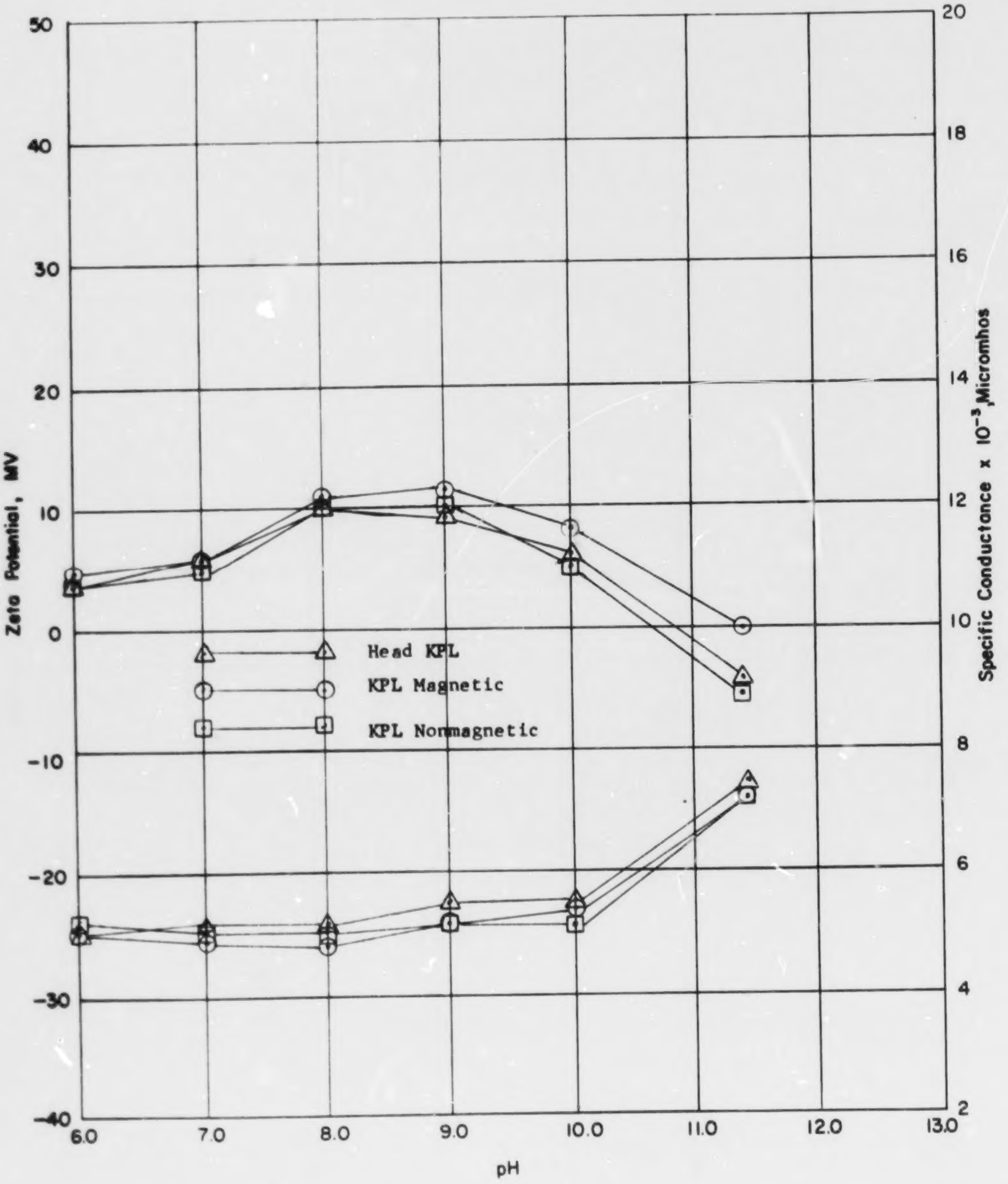


FIGURE 72B

THE EFFECT ON ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE HEAD, 3,000 GAUSS MAGNETIC AND 3,000 GAUSS NONMAGNETIC SAMPLES OF WET COLLECTED LIMESTONE MODIFIED FLYASH SAMPLE KPL AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1 POUND PER TON TO TRIVALENT ALUMINUM AS ALUMINUM POTASSIUM SULFATE AT A 1.0 PERCENT SLURRY CONCENTRATION

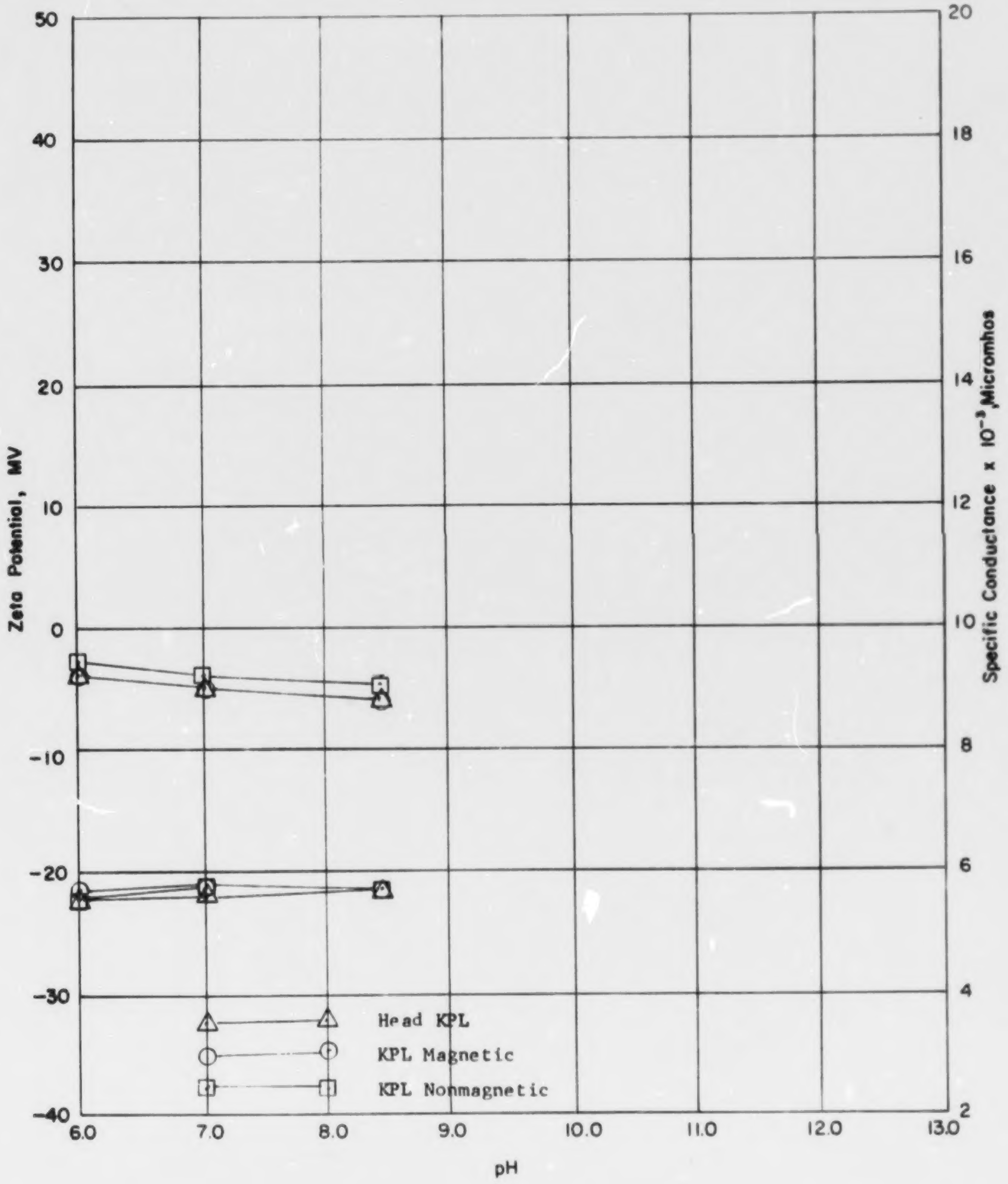


FIGURE 74B

THE EFFECT ON ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE HEAD, 3,000 GAUSS MAGNETIC AND 3,000 GAUSS NONMAGNETIC SAMPLES OF WET COLLECTED LIMESTONE MODIFIED FLYASH SAMPLE KPL AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 1 POUND PER TON OF THE PHOSPHATE RADICAL AS PHOSPHORIC ACID AT A 1.0 PERCENT SLURRY CONCENTRATION

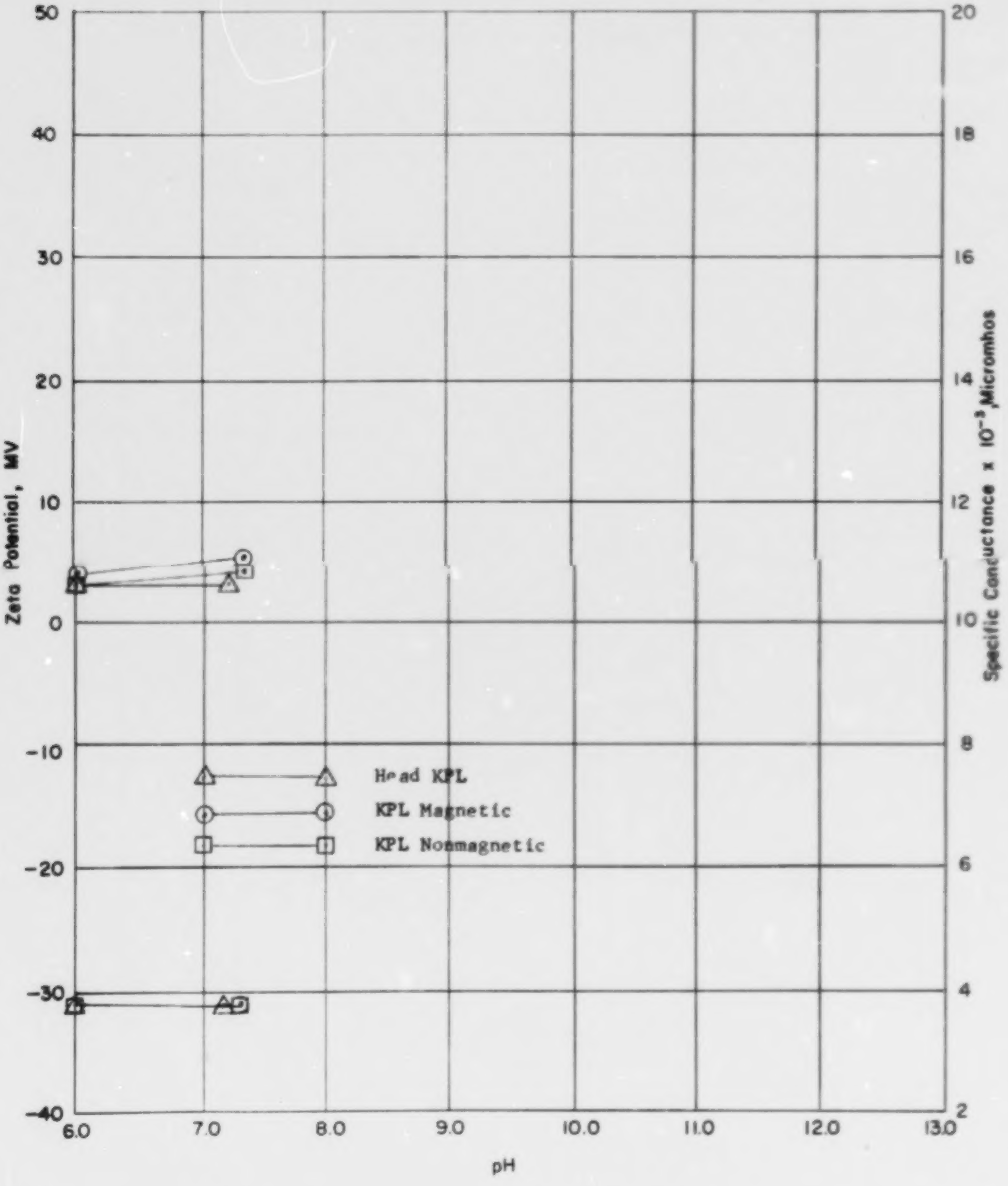
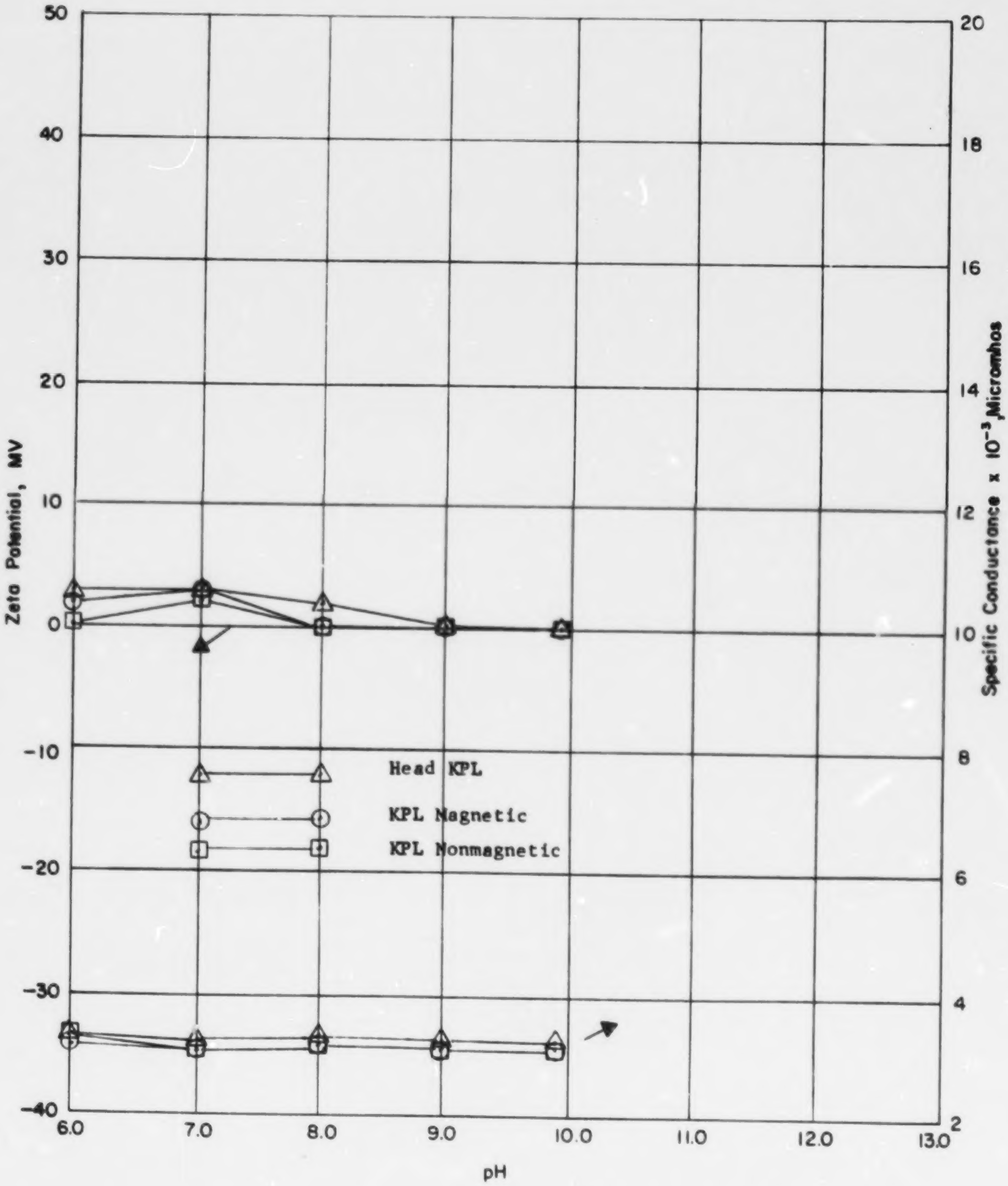


FIGURE 75B

THE EFFECT ON ZETA POTENTIAL AND SPECIFIC CONDUCTANCE OF THE HEAD, 3,000 GAUSS MAGNETIC AND 3,000 GAUSS NONMAGNETIC SAMPLES OF WET COLLECTED LIMESTONE MODIFIED FLYASH SAMPLE KPL AT VARIOUS LEVELS OF pH AFTER THE ADDITION OF 5 POUNDS PER TON OF STARCH AT A 1.0 PERCENT SLURRY CONCENTRATION



# APPENDIX C

# CARBONATION DATA

# FIGURE 1C

THE EFFECT OF CARBONATION ON THE pH OF 33 PERCENT
SLURRIES OF LIMESTONE MODIFIED FLYASH PID
(St. Clair, Mich.)

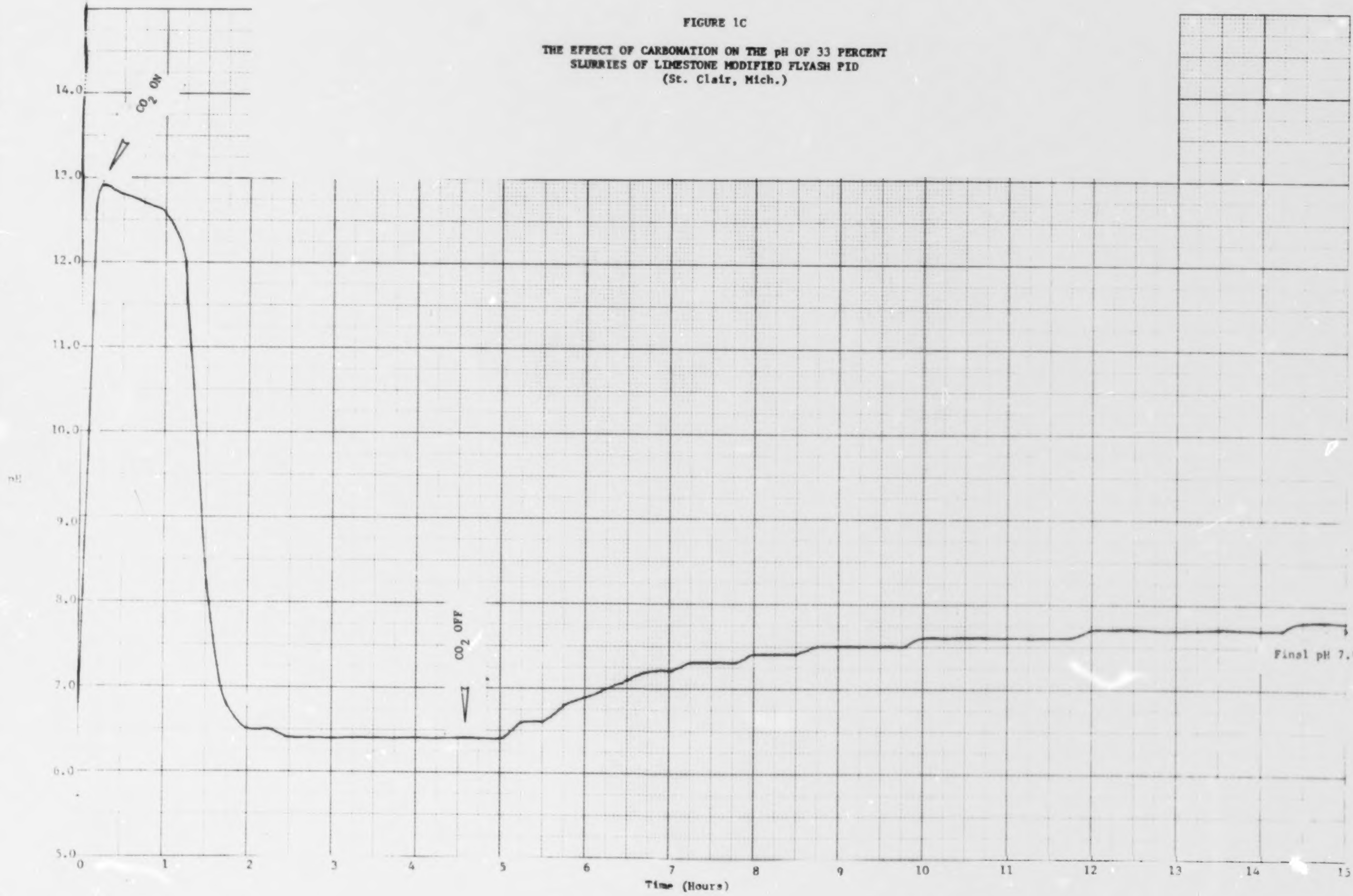


FIGURE 2C

THE EFFECT OF CARBONATION ON THE pH OF 33 PERCENT SLURRIES OF LIMESTONE MODIFIED FLYASH D1D2 (TVA)

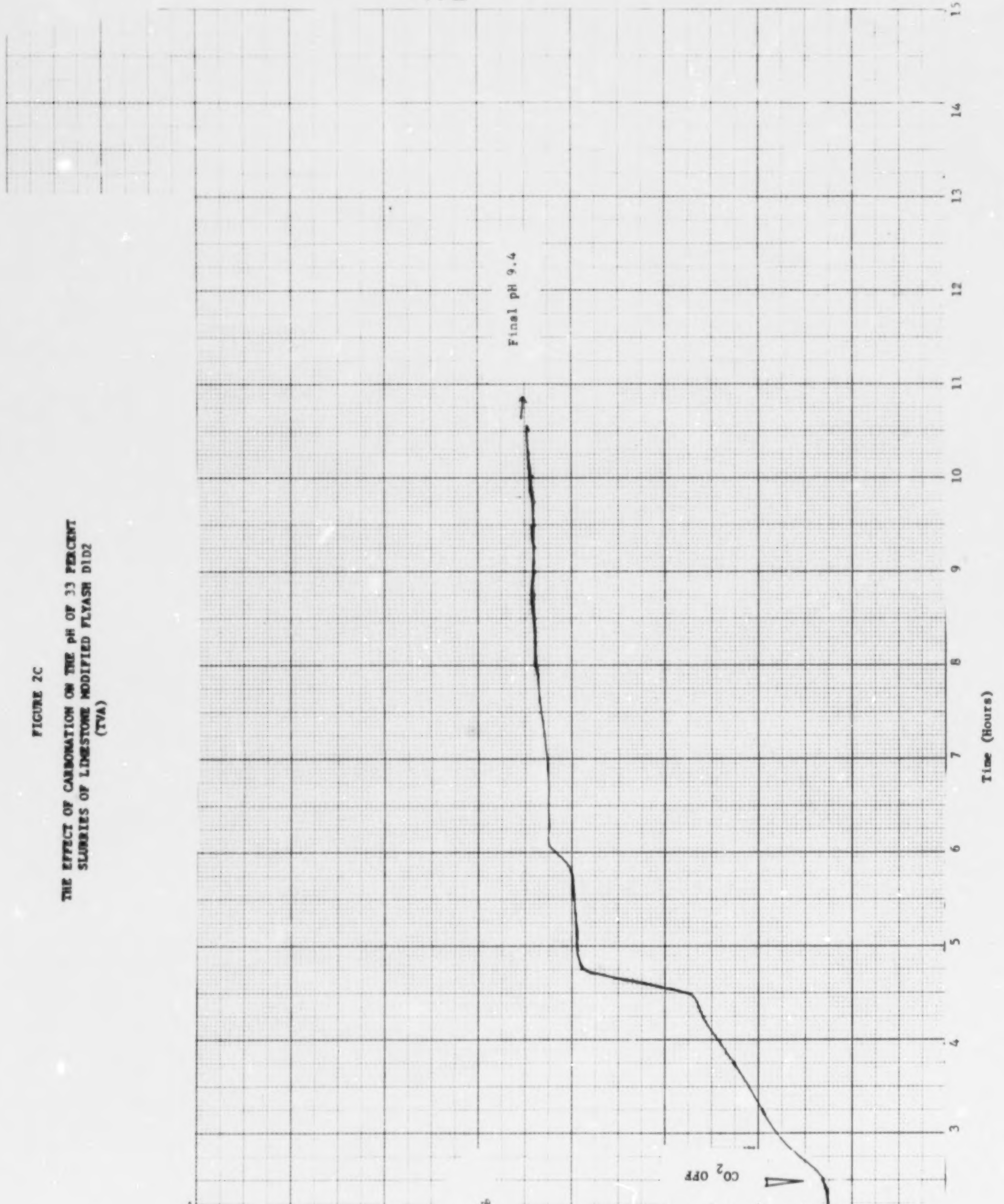


FIGURE 3C

THE EFFECT OF CARBONATION ON THE pH OF 33 PERCENT SLURRIES OF LIMESTONE MODIFIED FLYASH D1D3 (TVA)

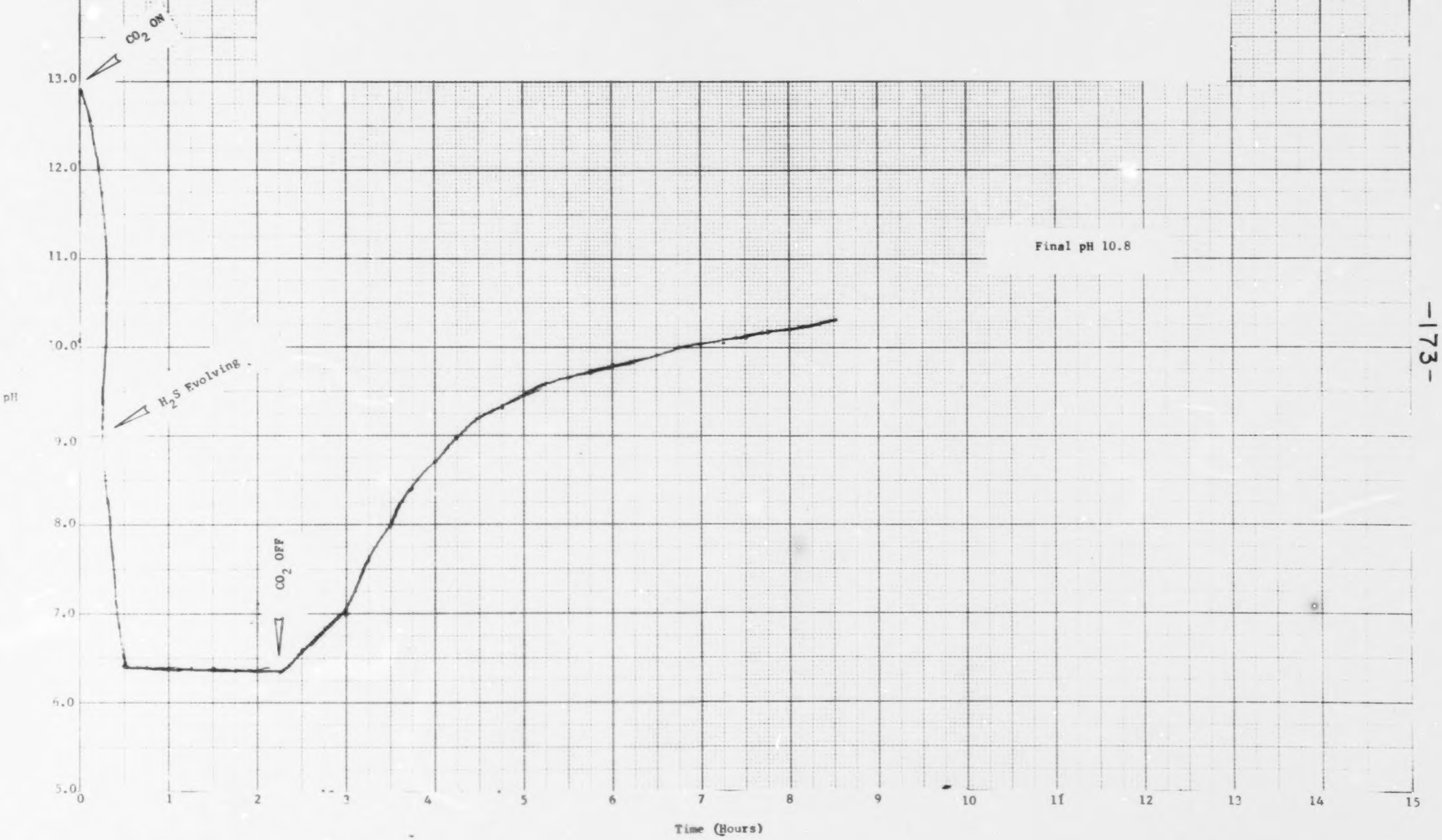
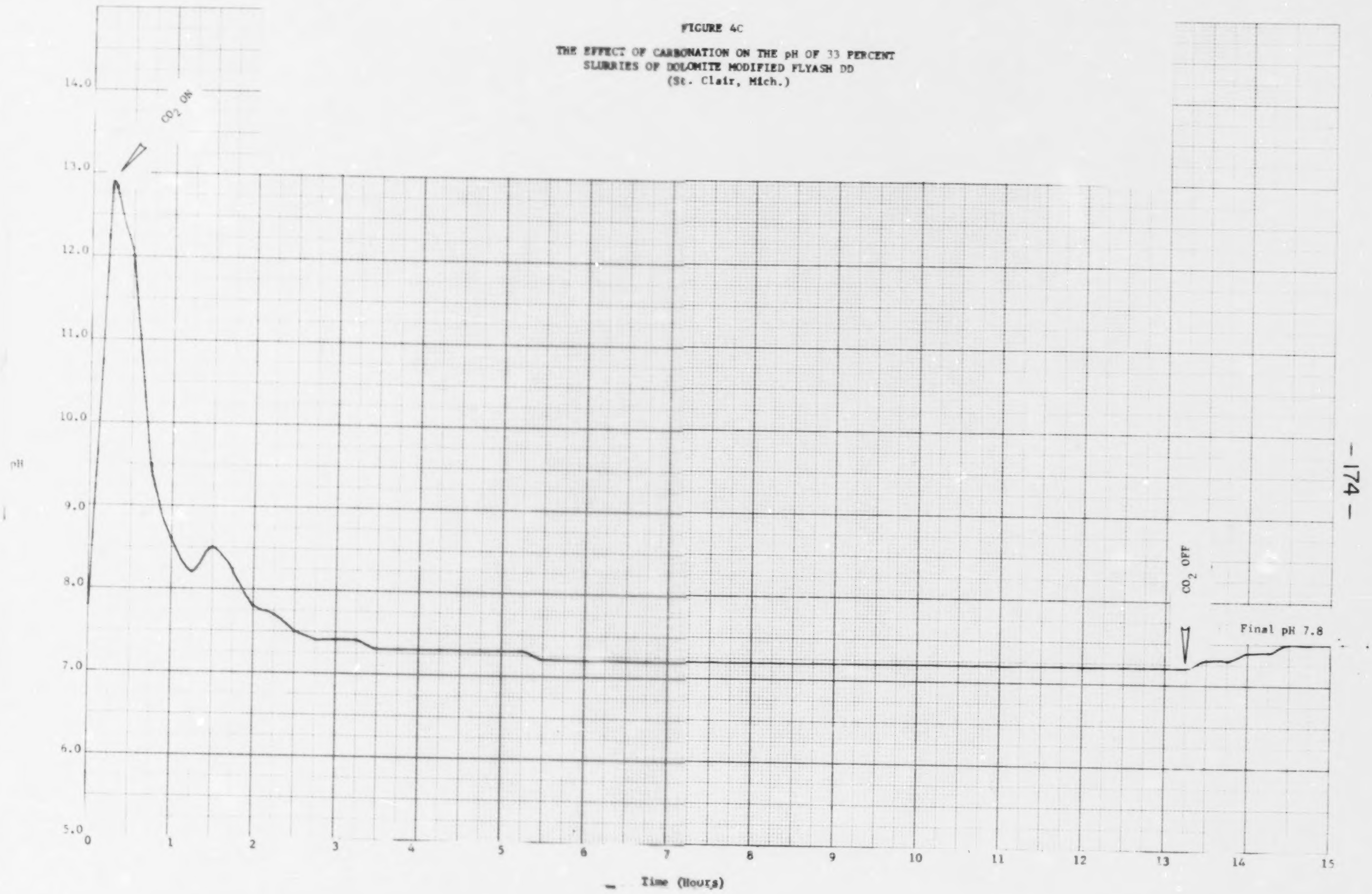


FIGURE 4C

THE EFFECT OF CARBONATION ON THE pH OF 33 PERCENT
SLURRIES OF DOLOMITE MODIFIED FLYASH DD
(St. Clair, Mich.)



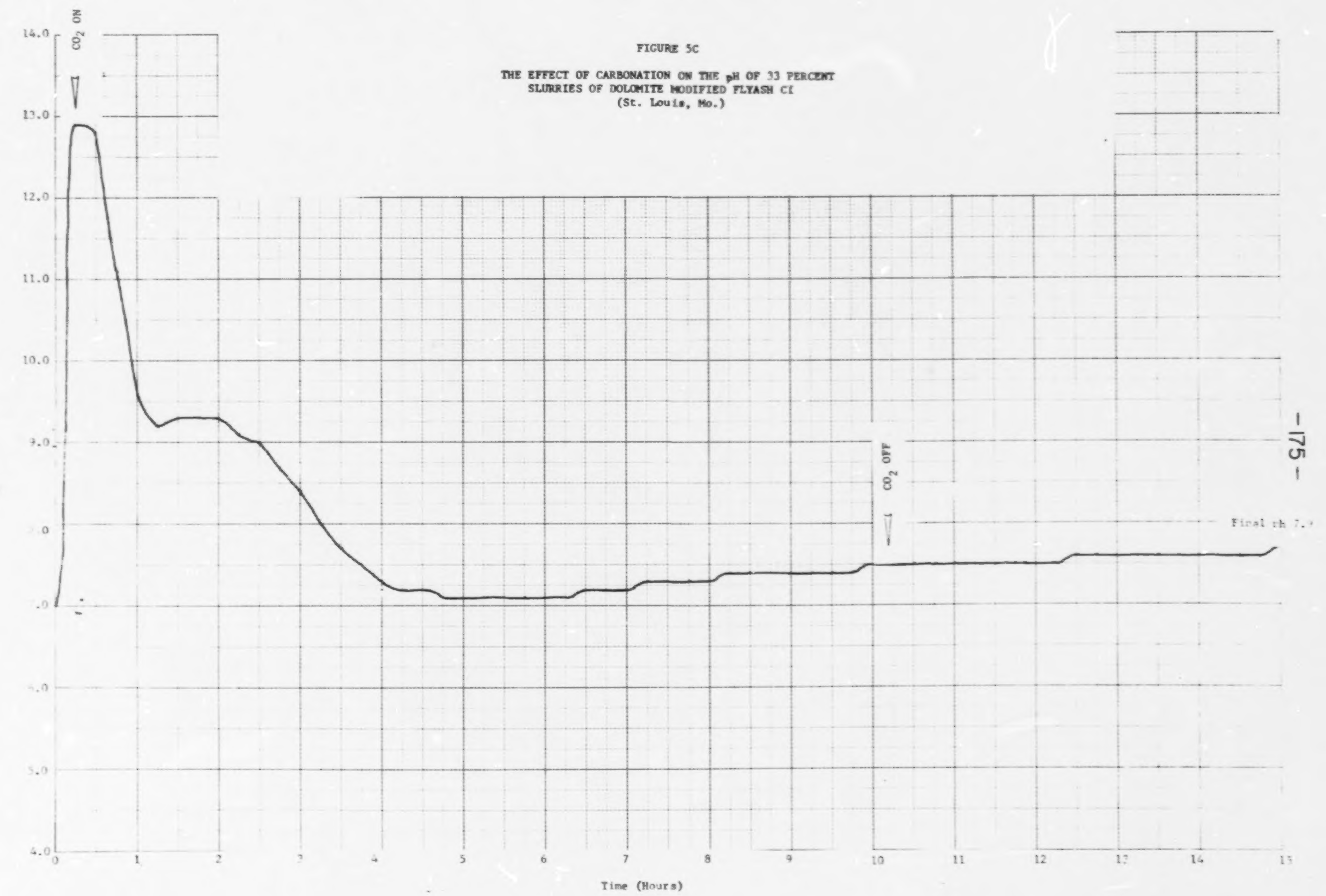


FIGURE 5C

THE EFFECT OF CARBONATION ON THE pH OF 33 PERCENT SLURRIES OF DOLOMITE MODIFIED FLYASH CI (St. Louis, Mo.)

FIGURE 6C

THE EFFECT OF CARBONATION ON THE pH OF 33 PERCENT SLURRIES OF DOLOMITE MODIFIED FLYASH CM
(St. Louis, Mo.)

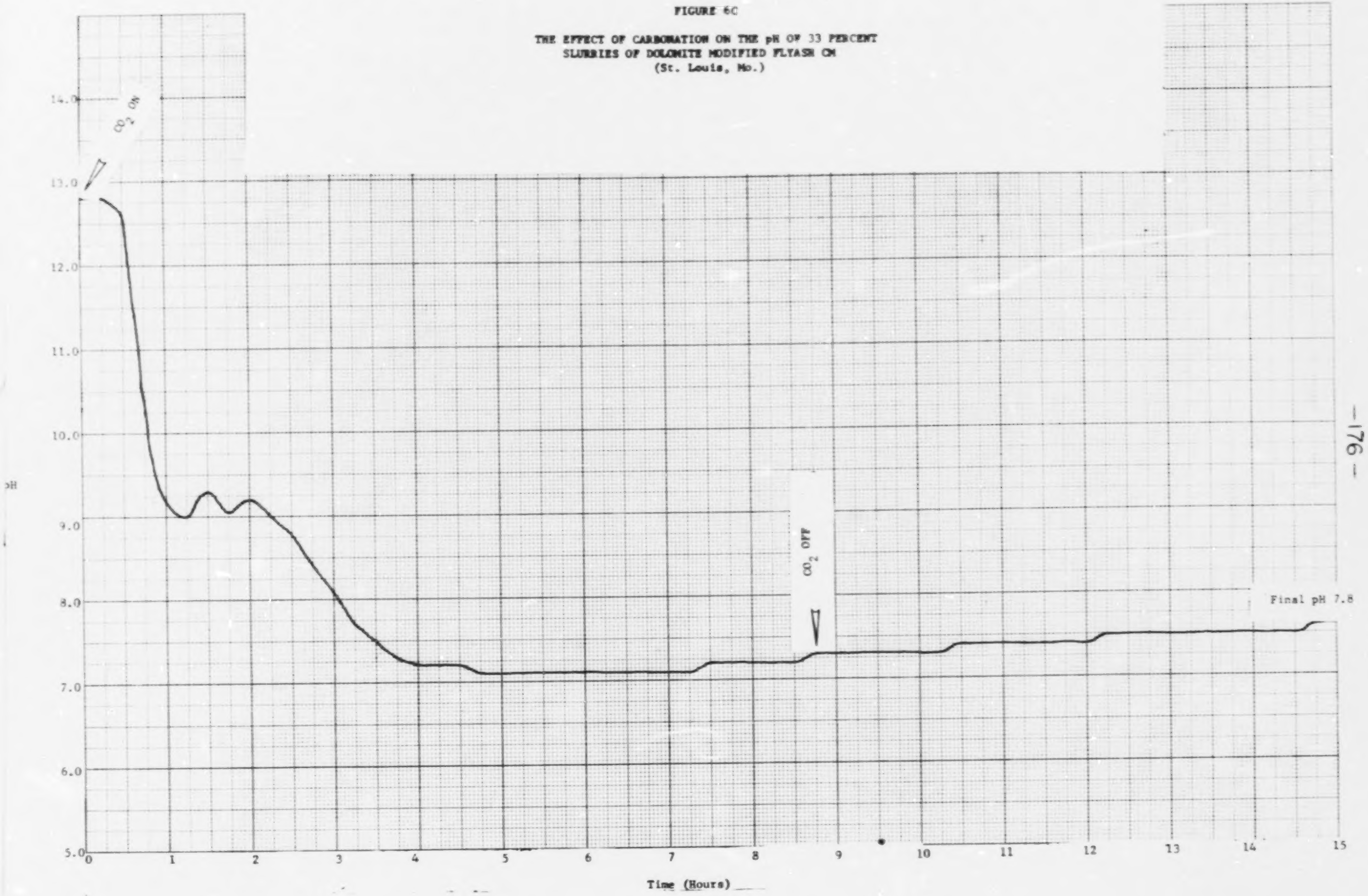


FIGURE 7C
THE CHANGE IN pH AND CARBON DIOXIDE ABSORPTION OF CI MODIFIED FLYASH, 16.6 PERCENT SLURRY

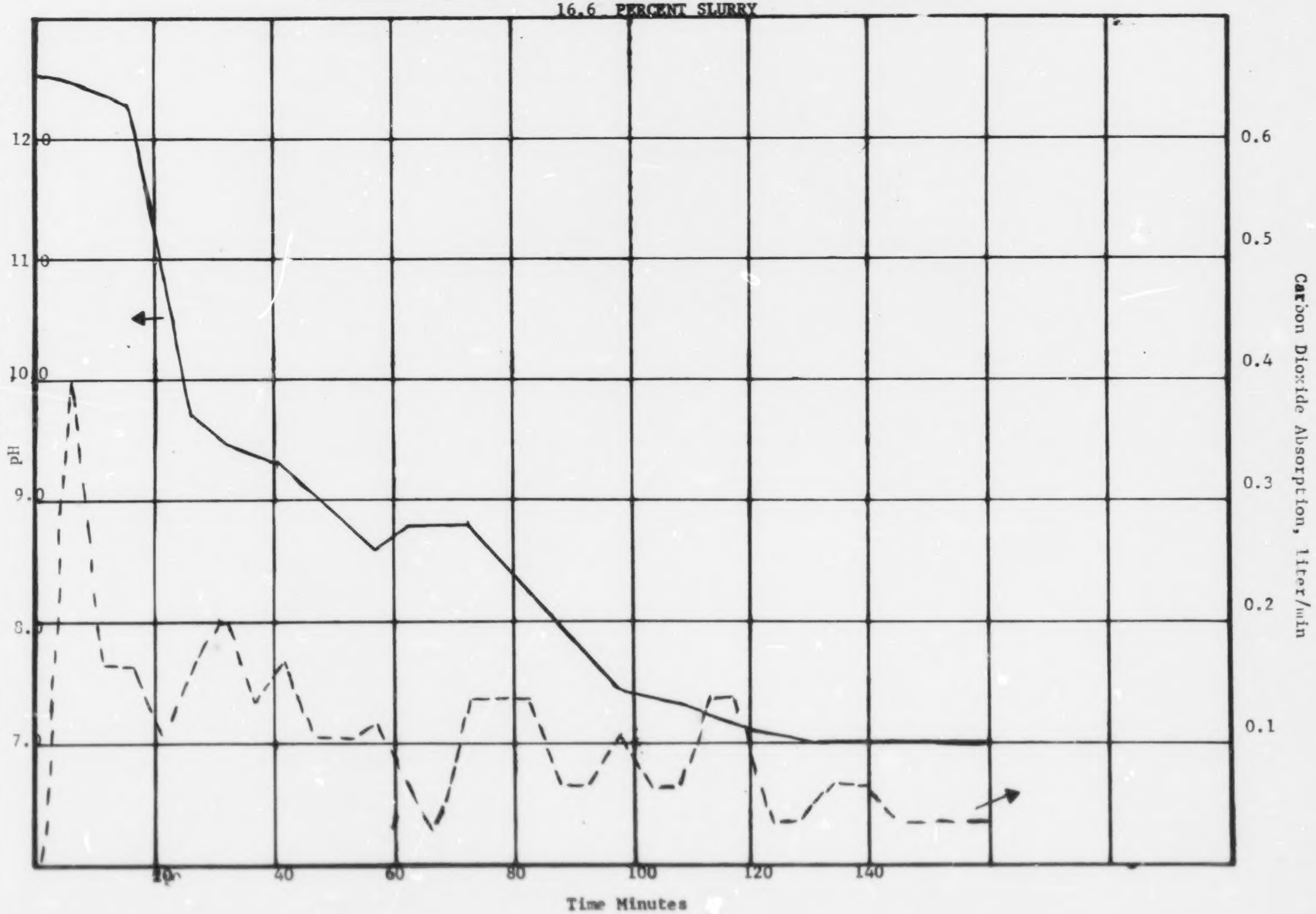


FIGURE 8C

THE CHANGE IN pH AND CARBON DIOXIDE ABSORPTION OF PID MODIFIED FLYASH, 16.5 PERCENT SLURRY

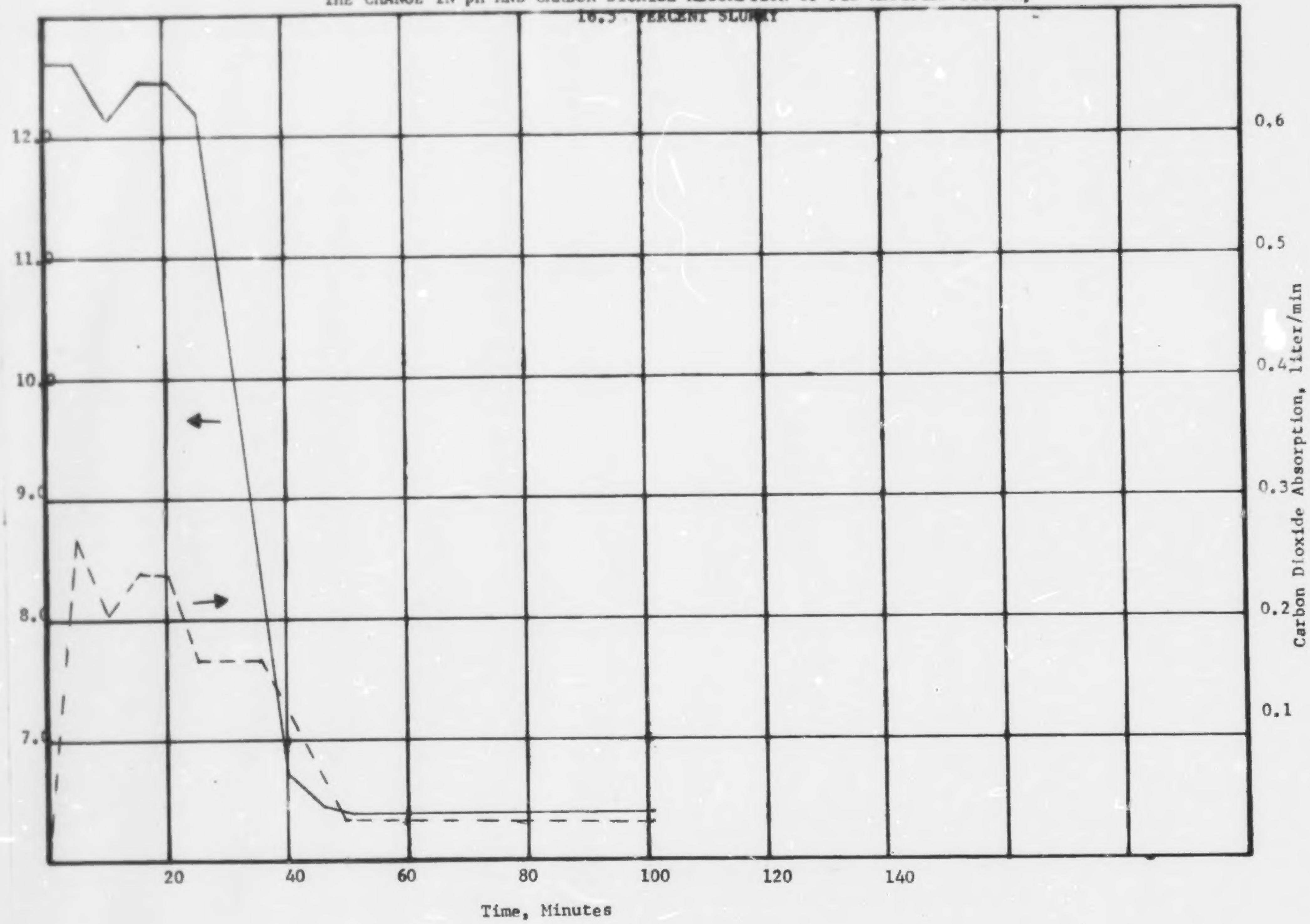


FIGURE 9C
THE CHANGE IN pH AND CARBON DIOXIDE ABSORPTION OF CM MODIFIED FLYASH,
16.6% WEIGHT SLURRY

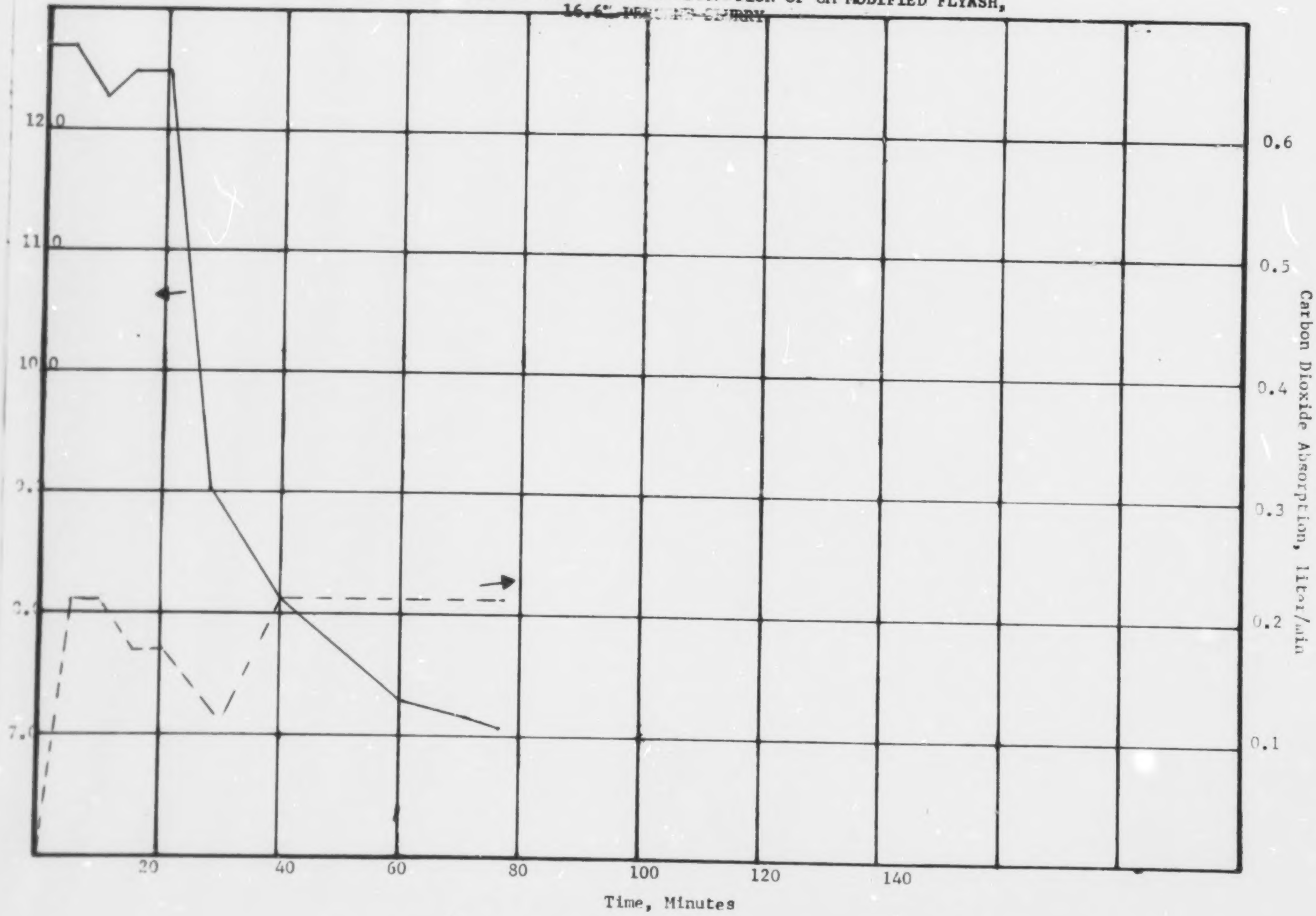
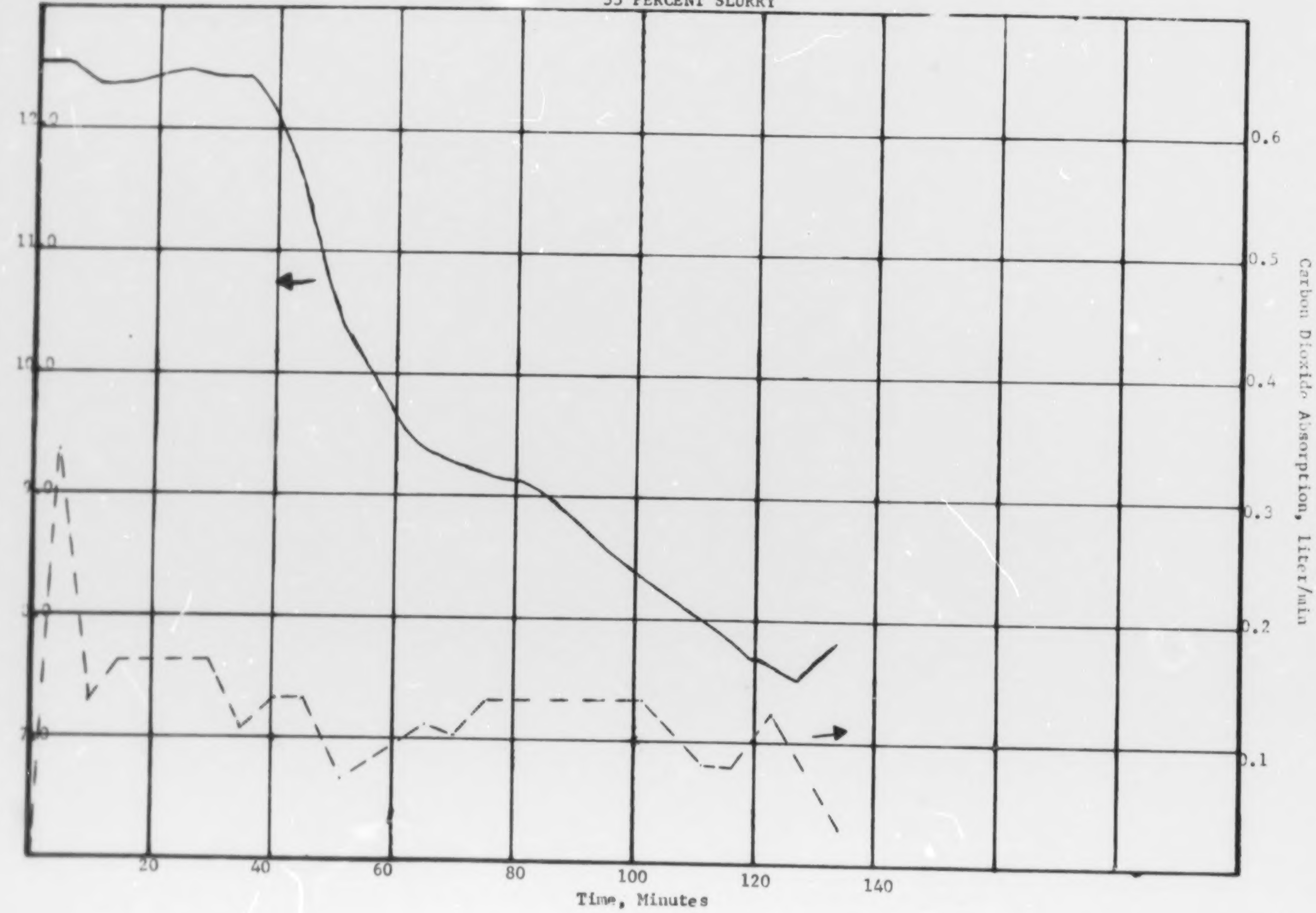


FIGURE 10C

THE CHANGE IN pH AND CARBON DIOXIDE ABSORPTION OF CM MODIFIED FLYASH, 33 PERCENT SLURRY



# APPENDIX D

# THERMOGRAVIMETRIC ANALYSIS (TGA) DATA

FIGURE 1D

THERMALGRAVIMETRIC ANALYSIS OF CALCIUM CARBONATE

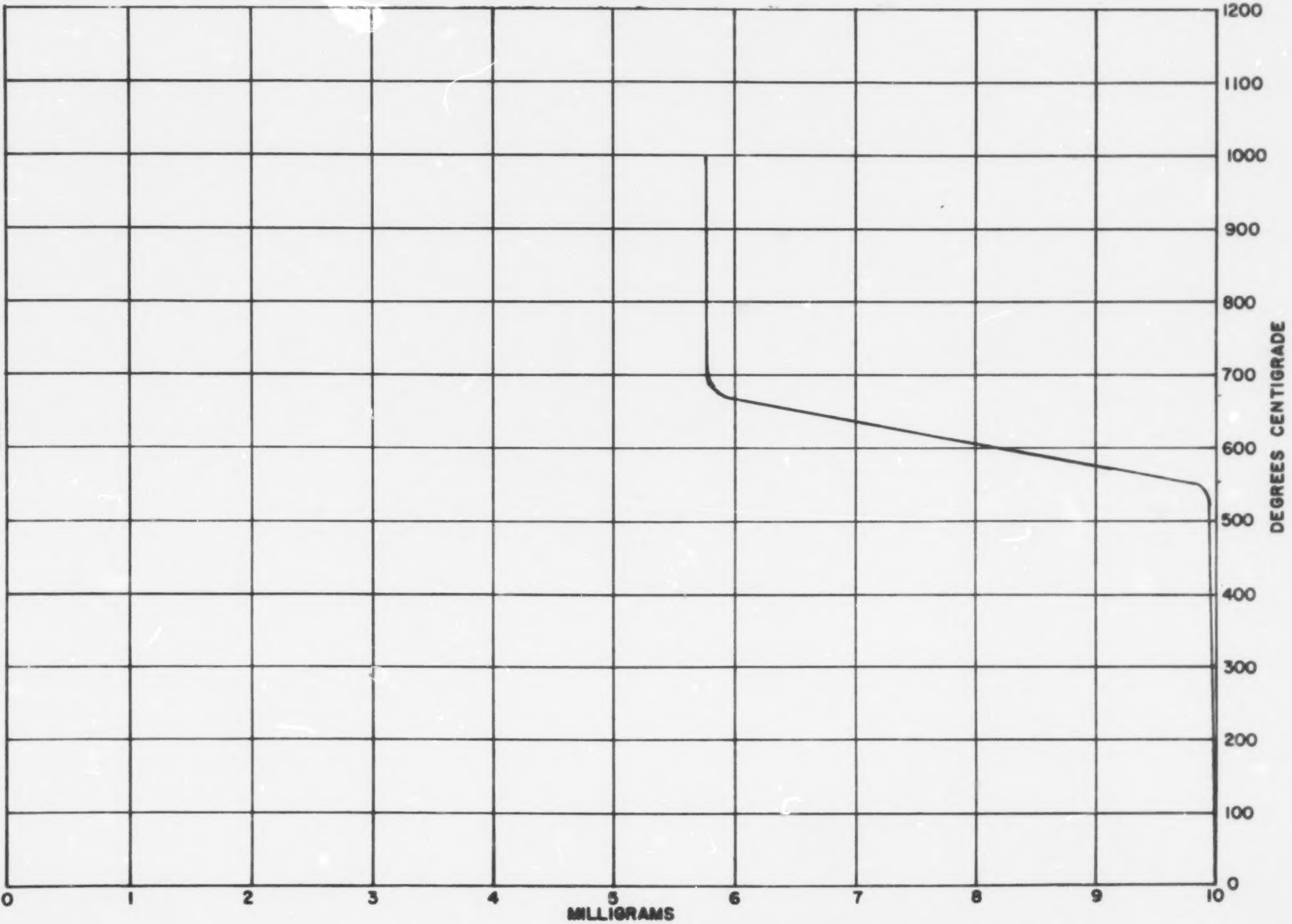


FIGURE 2D

THERMALGRAVIMETRIC ANALYSIS OF CALCIUM SULFATE

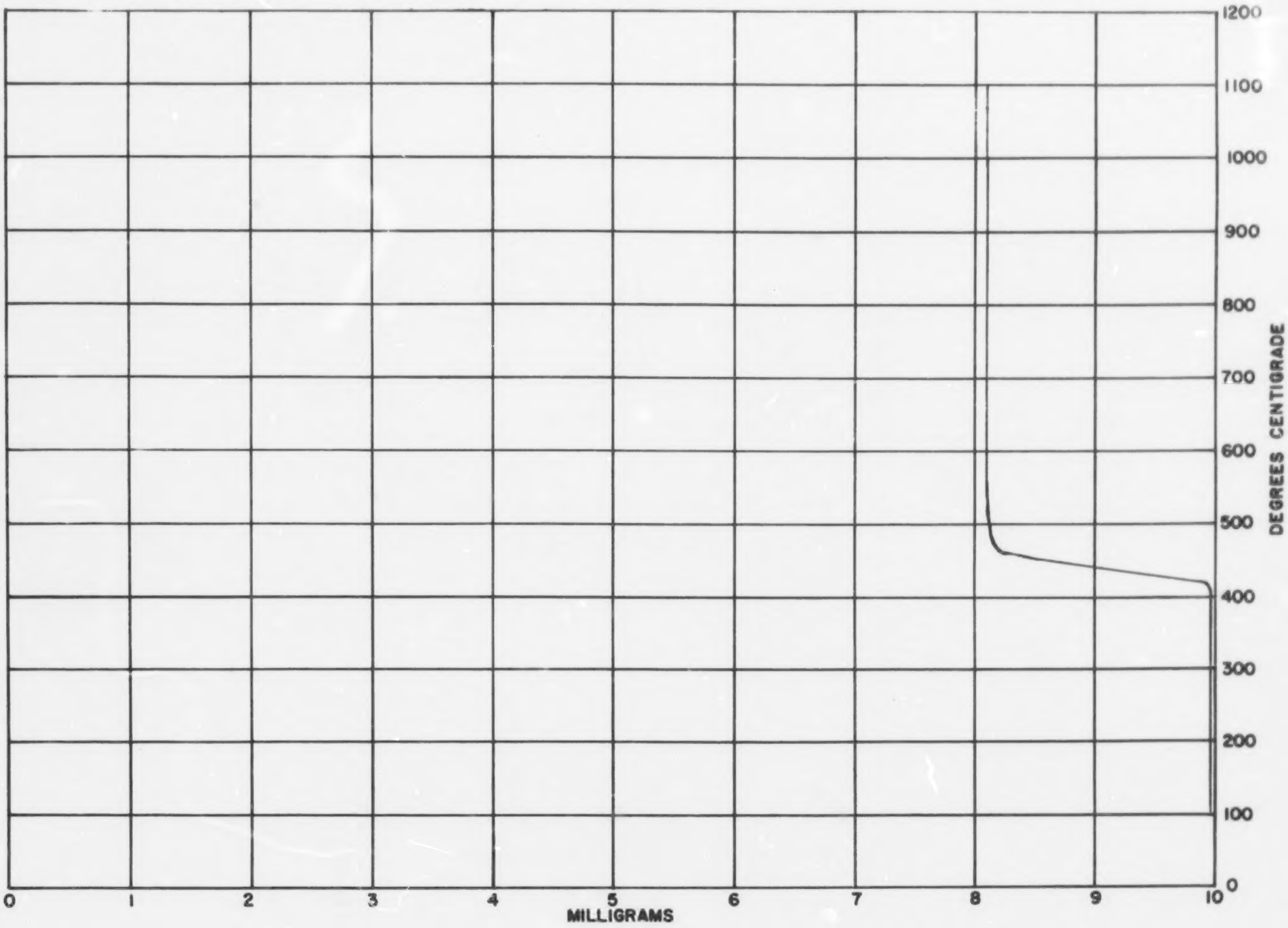


FIGURE 3D
THERMALGRAVIMETRIC ANALYSIS OF CALCIUM SULFITE

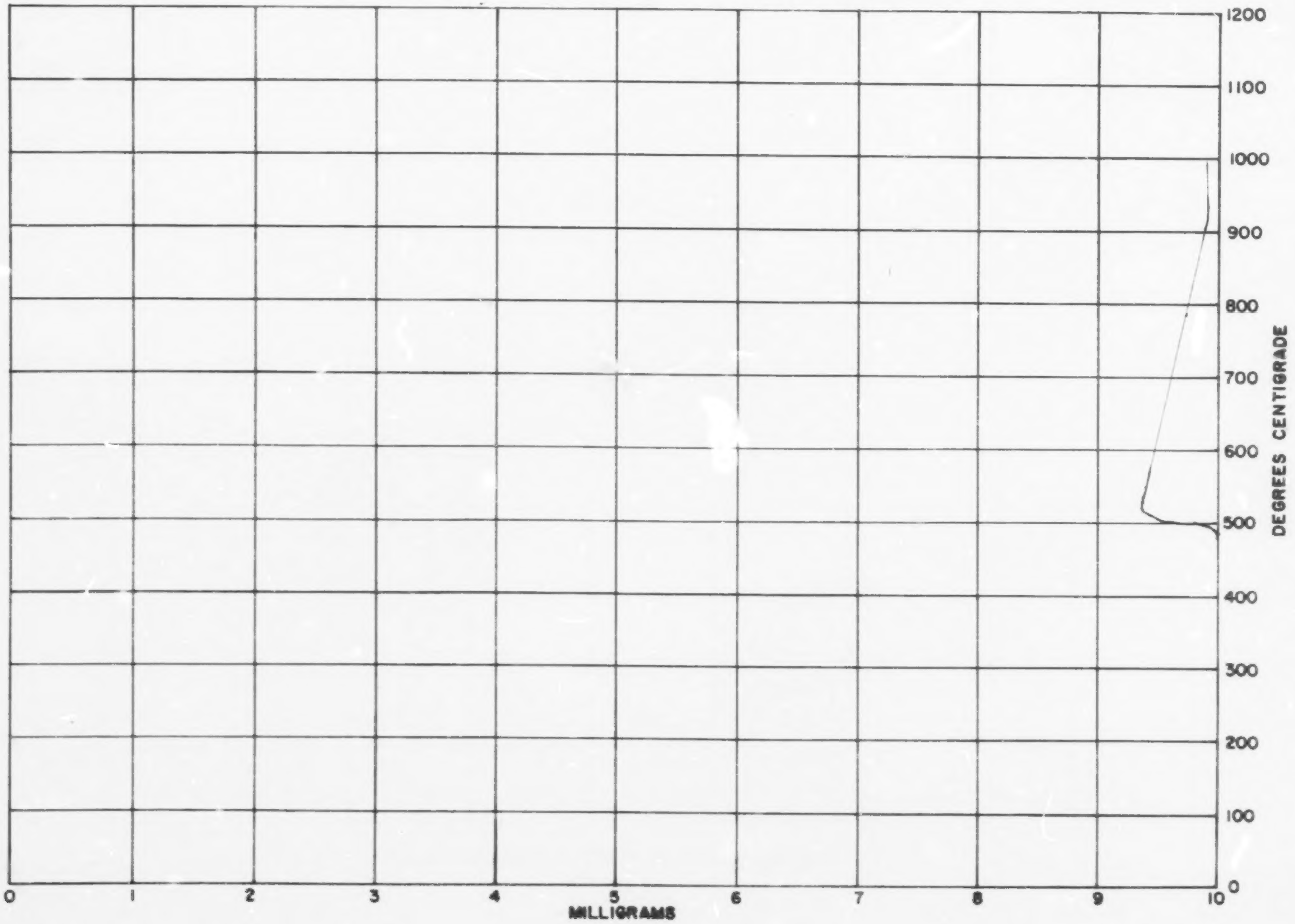


**FIGURE 4D**

THERMALGRAVIMETRIC ANALYSIS OF CALCIUM OXIDE

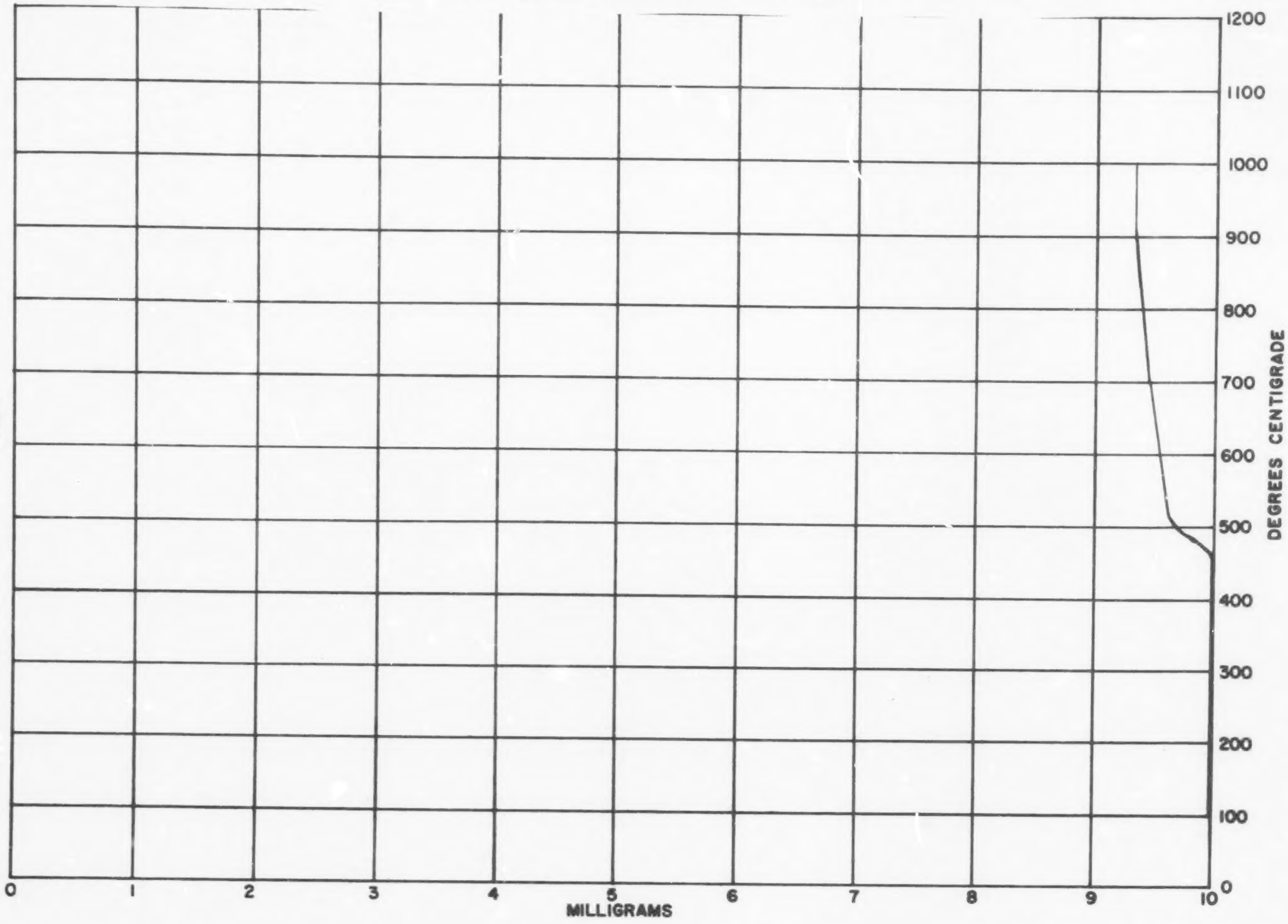


FIGURE 5D
THERMALGRAVIMETRIC ANALYSIS OF WET COLLECTED LIMESTONE MODIFIED FLYASH
KANSAS POWER AND LIGHT CONTAINING 22.84 PERCENT LIME

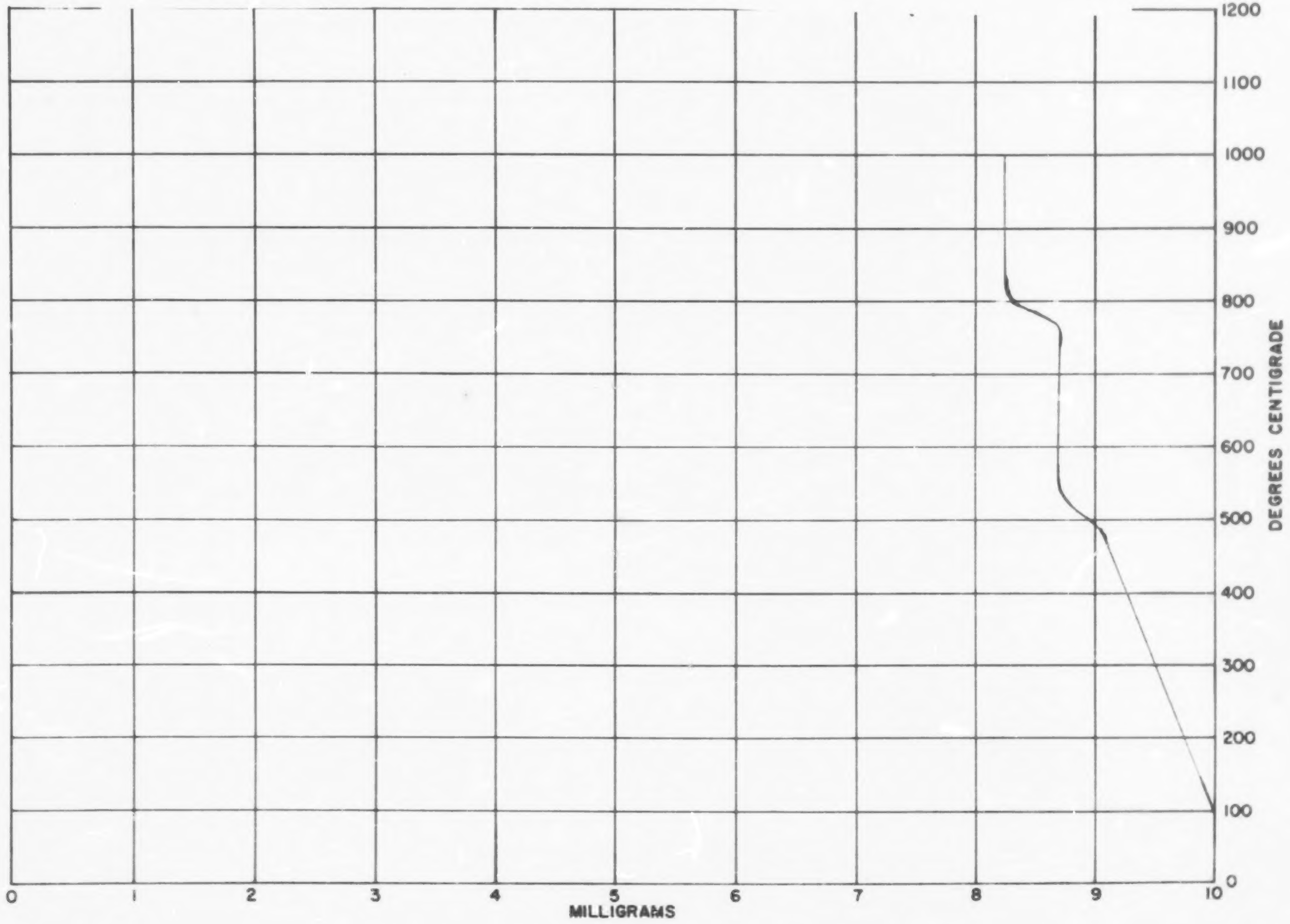


FIGURE 6D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690581 THE CC$_2$ OF TEST 111 CONTAINING
49.74 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

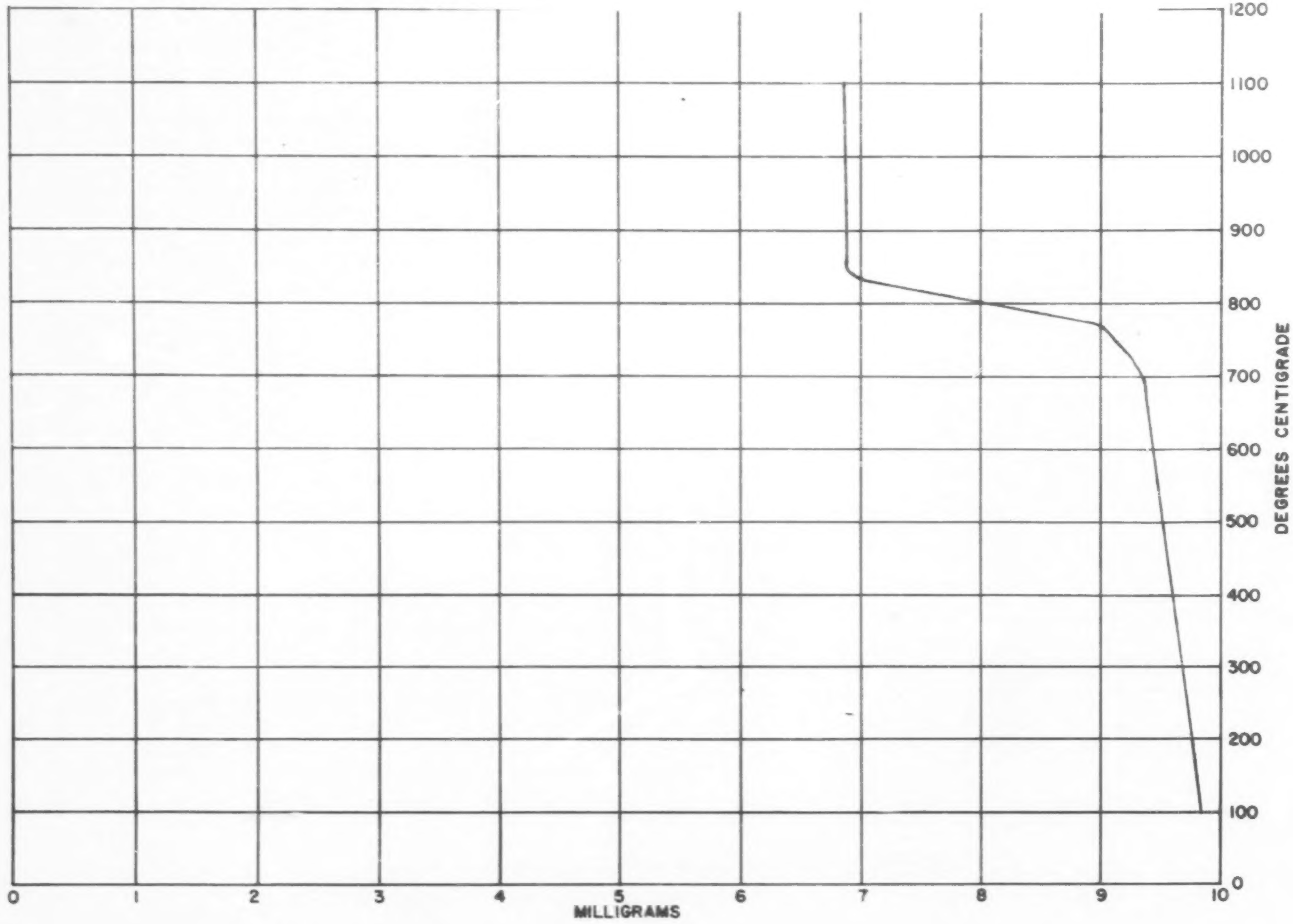


FIGURE 7D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690582 THE SC OF TEST 111 CONTAINING
39.72 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

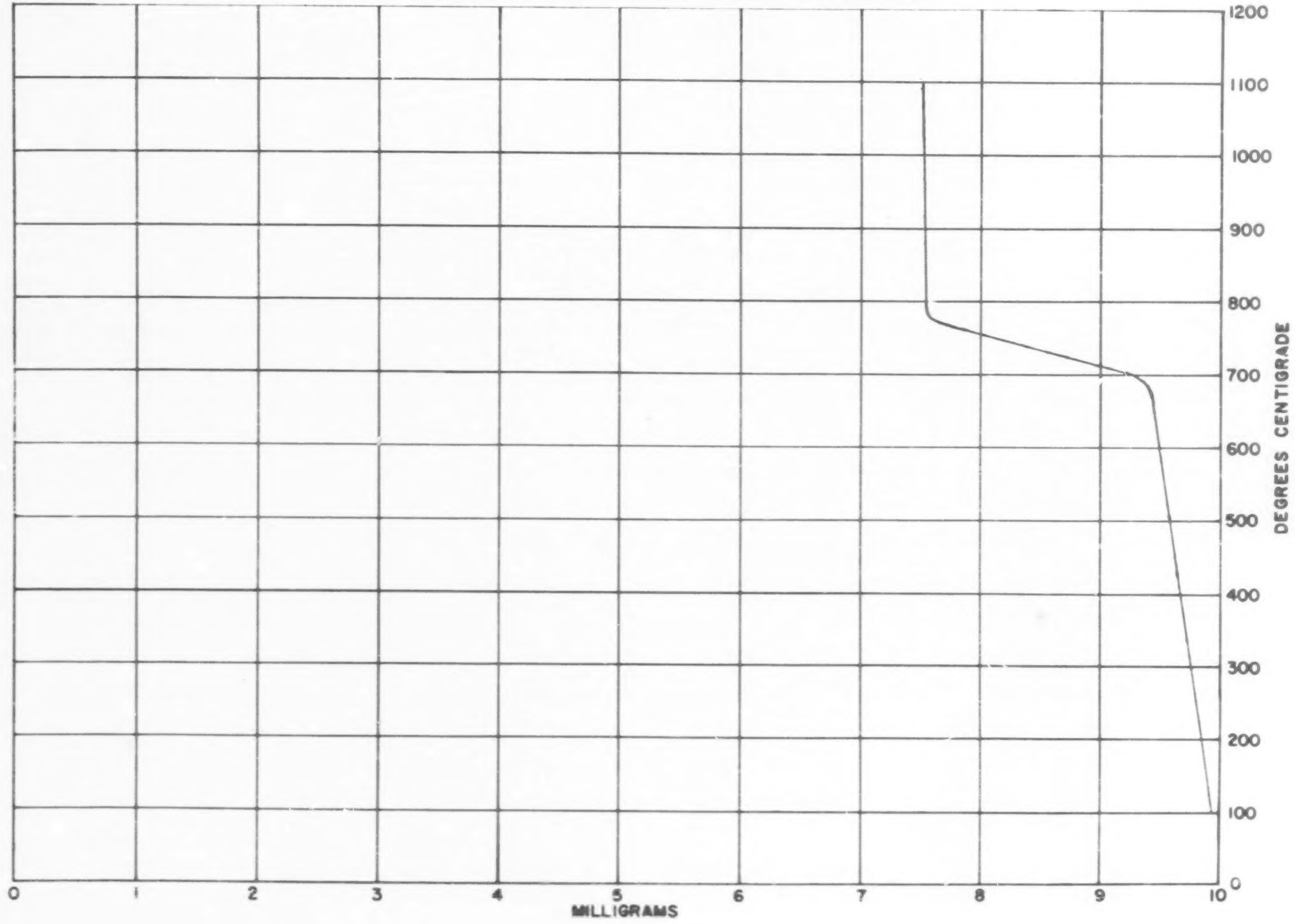


FIGURE 8D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690583 THE TT$_1$ OF TEST 111 CONTAINING
15.84 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

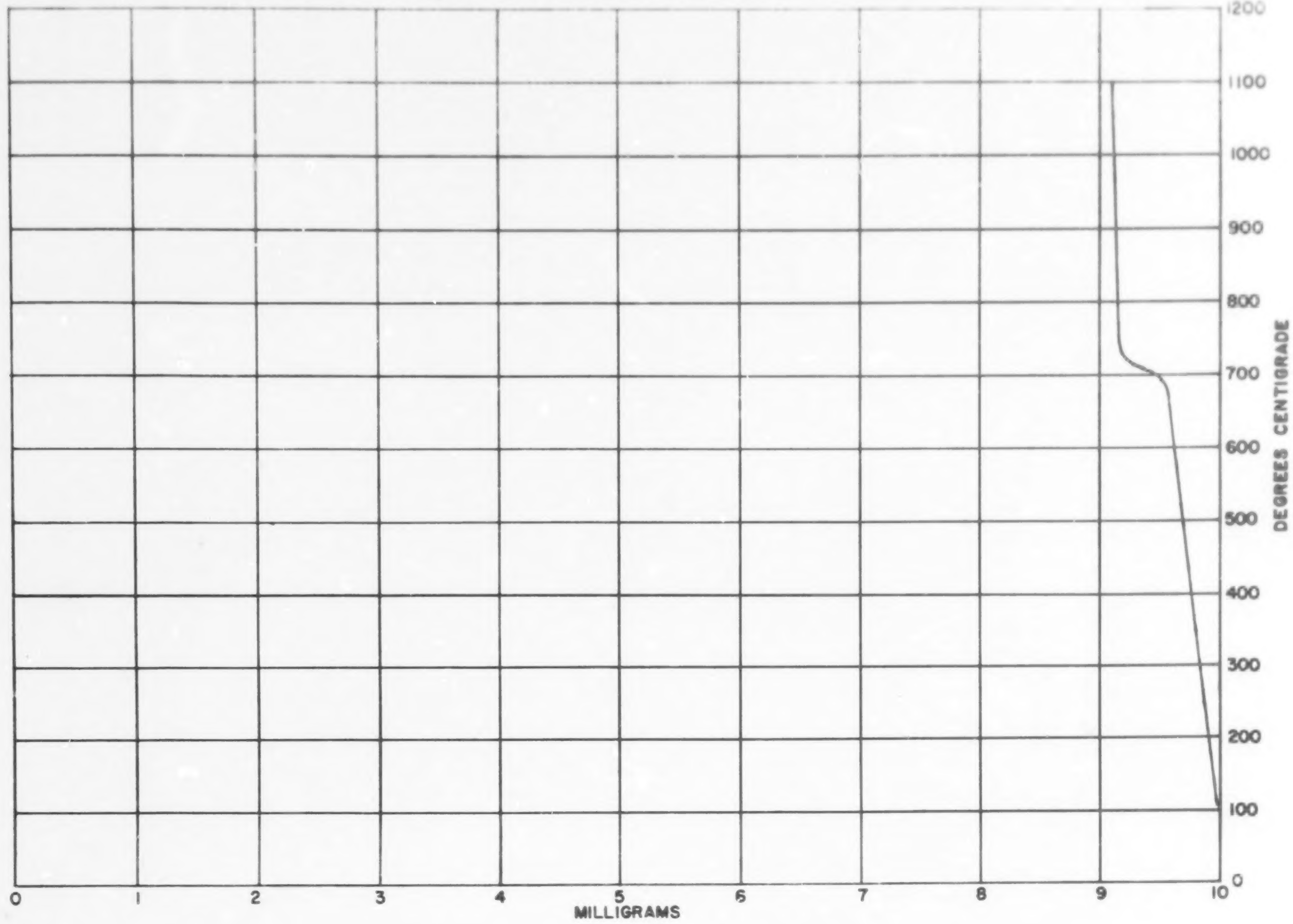


FIGURE 9D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690584 THE TT$_2$ OF TEST 111 CONTAINING 19.82 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

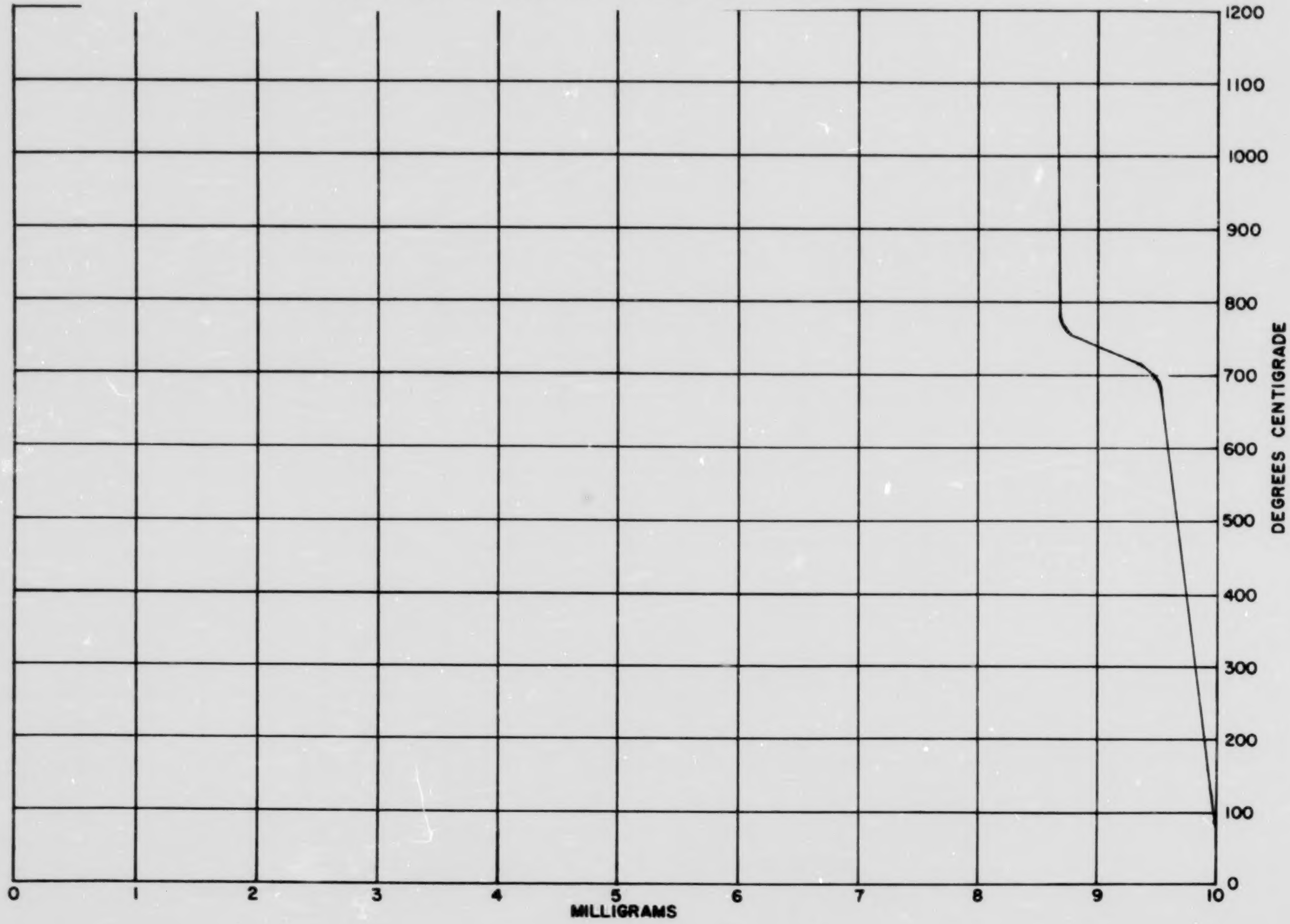


FIGURE 10D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690585 THE $TC_2$ OF TEST 111 CONTAINING
27.39 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

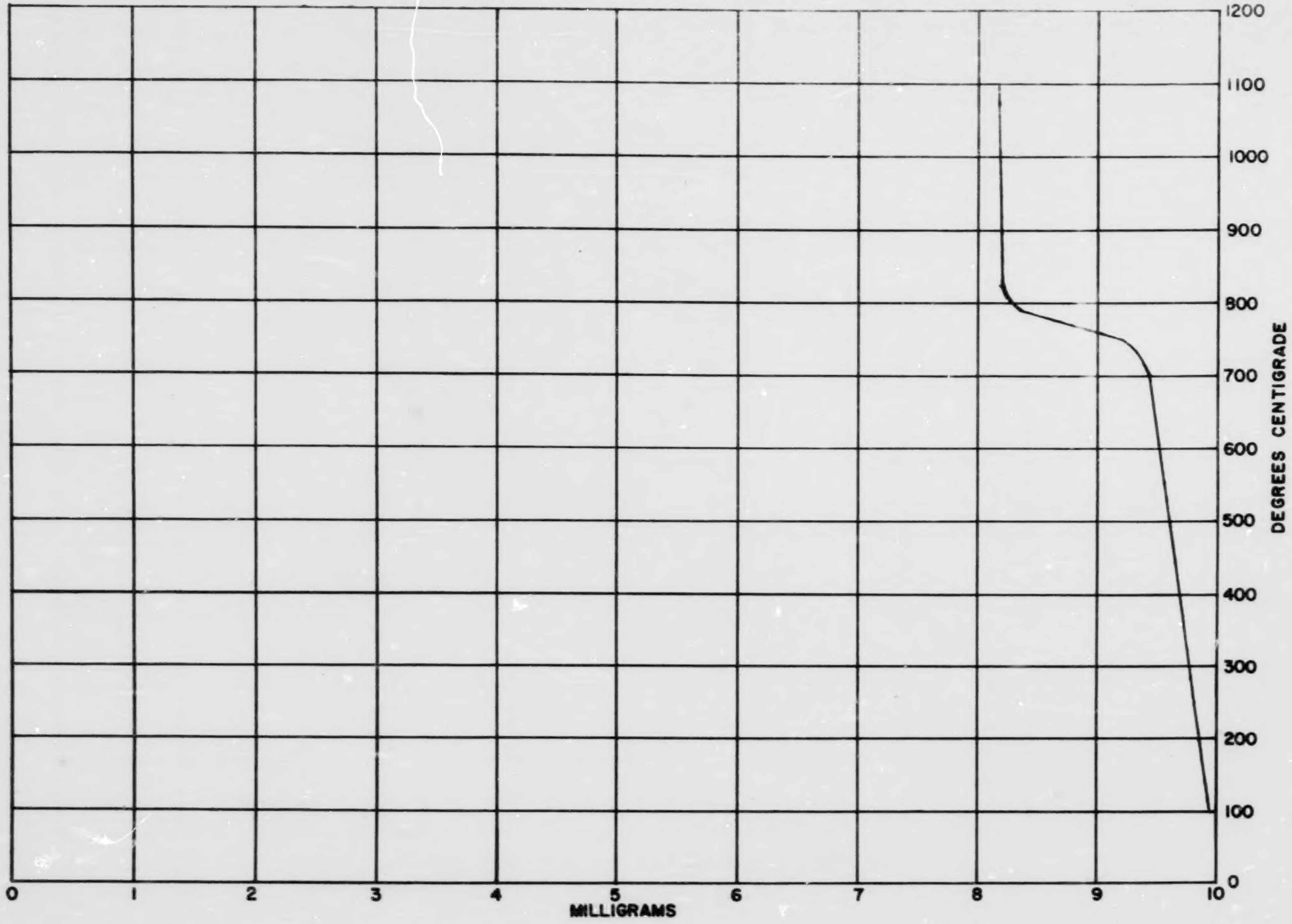


FIGURE 11D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 700032 THE $CC_2$ OF TEST 121 CONTAINING
47.47 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

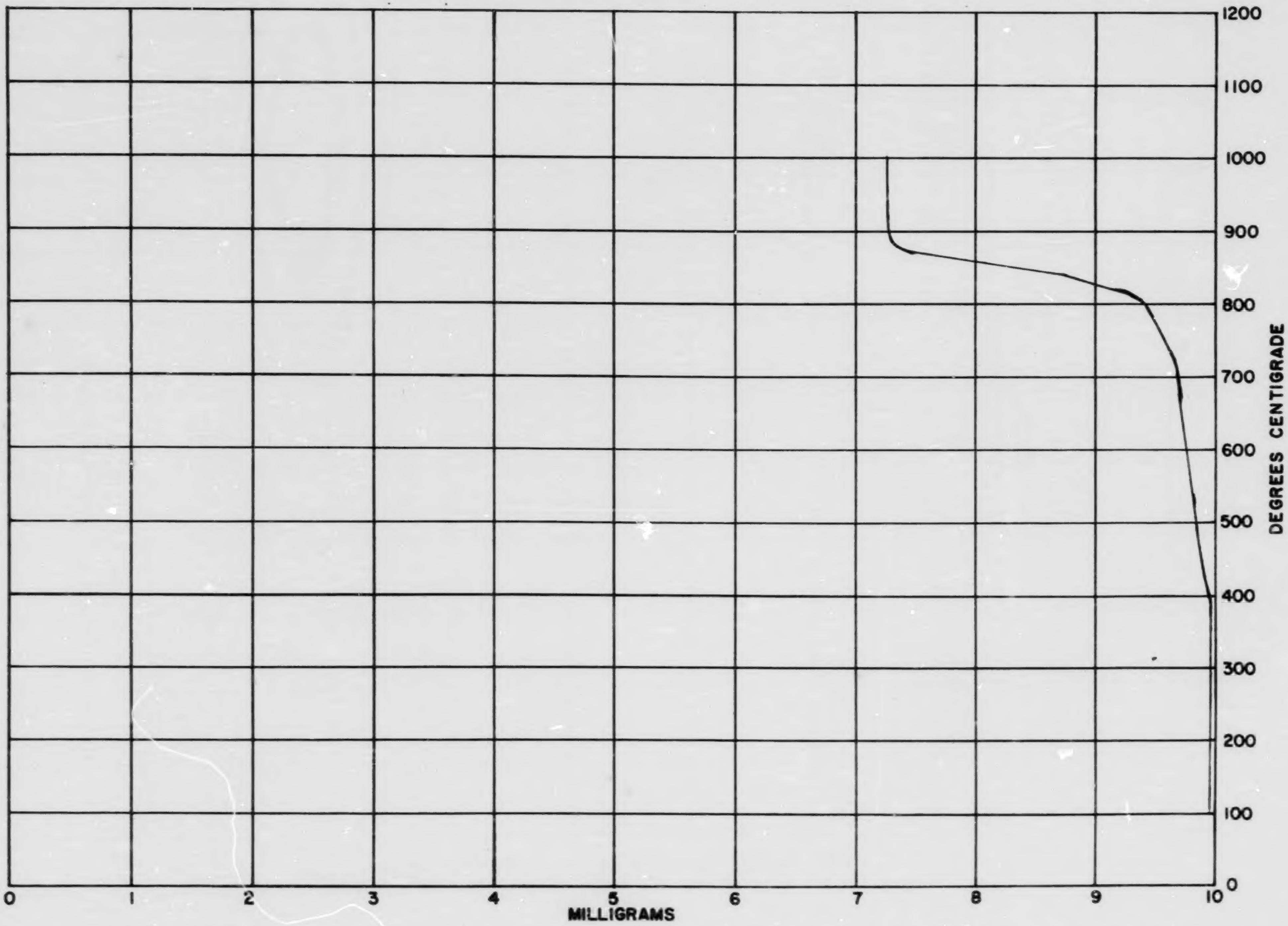


FIGURE 12D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 700033 THE $CC_4$ OF TEST 121 CONTAINING
43.84 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

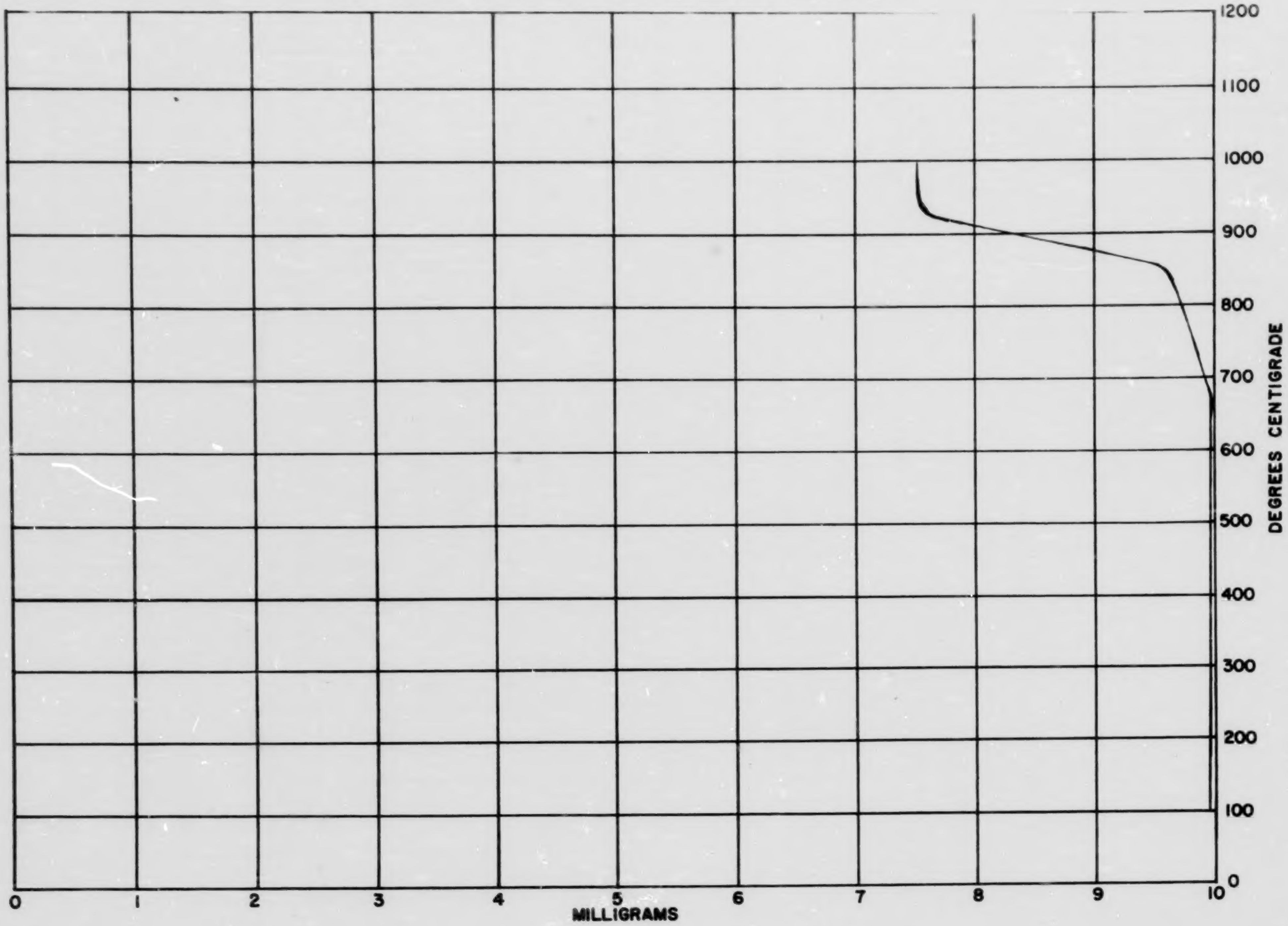


FIGURE 13D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 700034 THE $CC_6$ OF TEST 121 CONTAINING
42.22 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

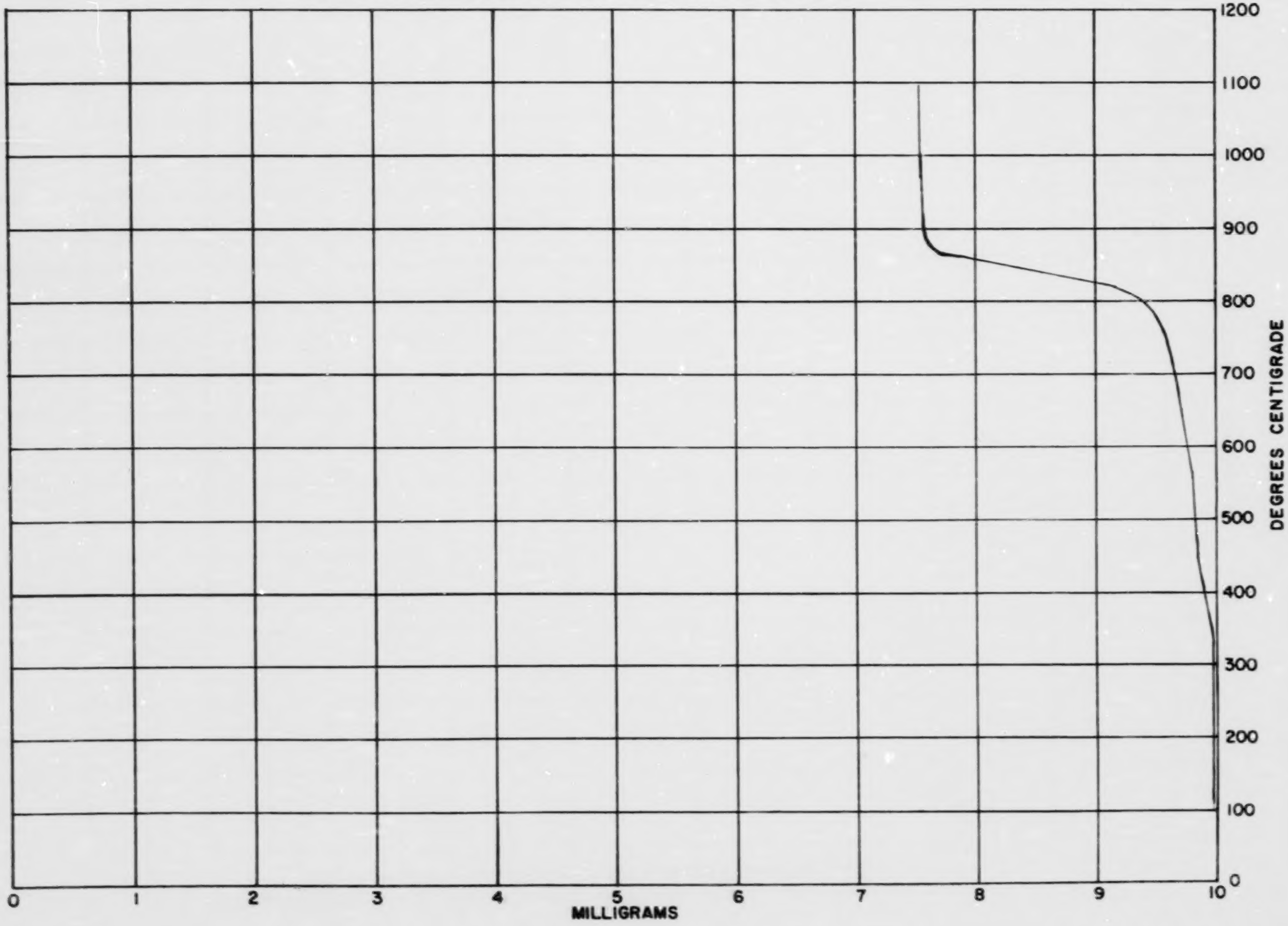


FIGURE 14D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 700035 THE $CC_8$ OF TEST 121 CONTAINING
36.40 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

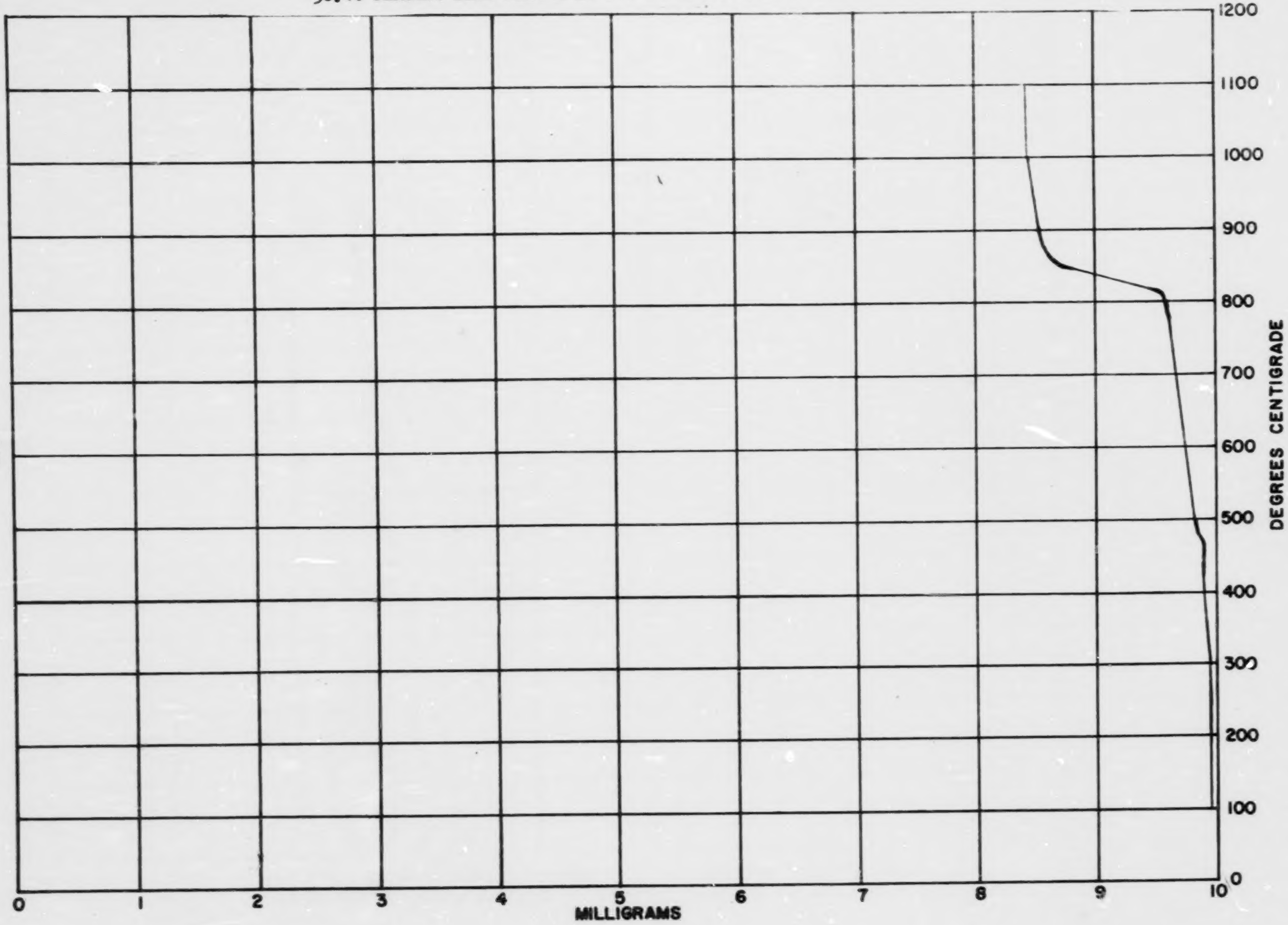


FIGURE 15D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 700036 THE $RT_4$ OF TEST 121 CONTAINING 22.58 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

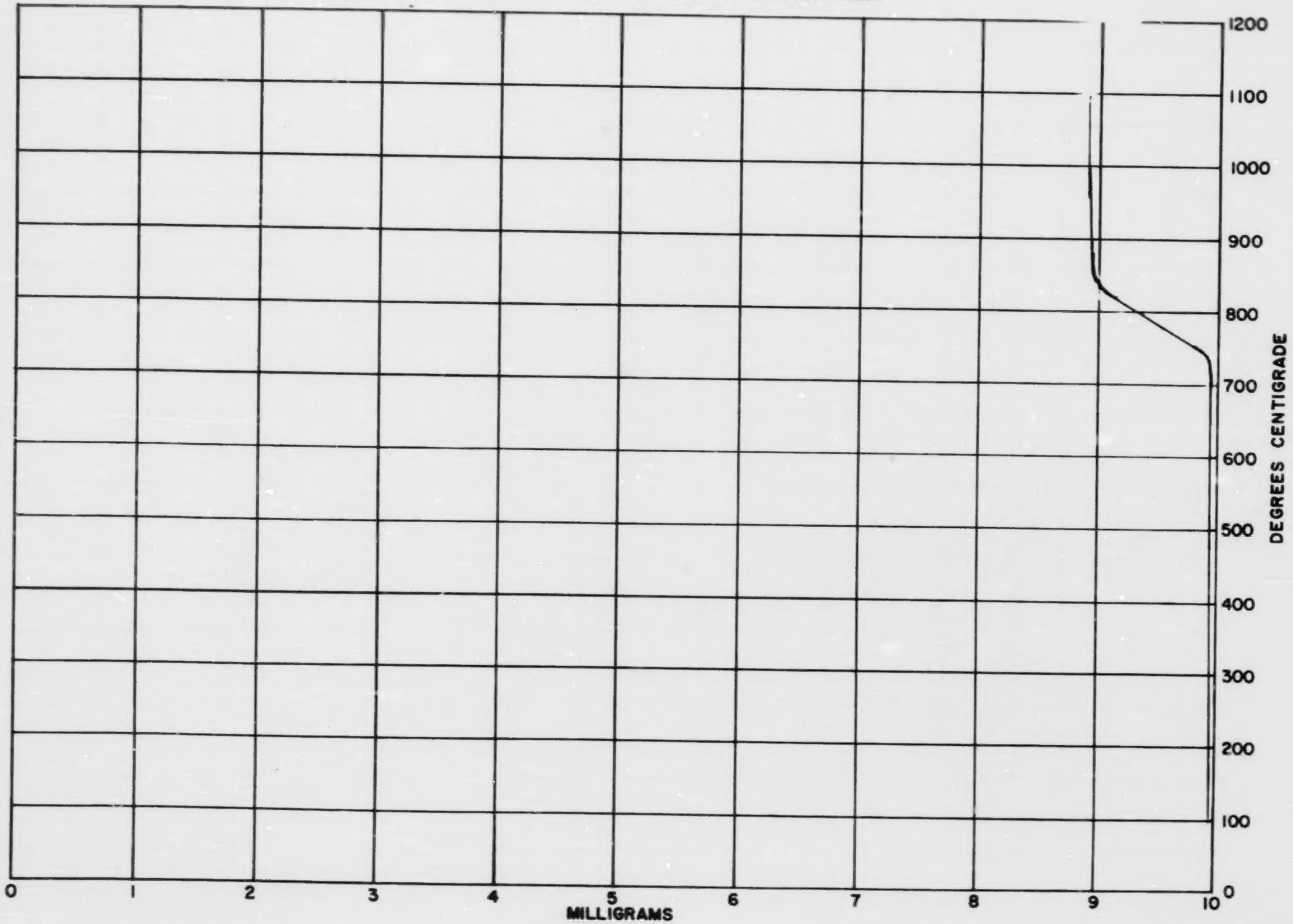


FIGURE 16D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 700037 THE $CT_7$ OF TEST 121 CONTAINING 26.34 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

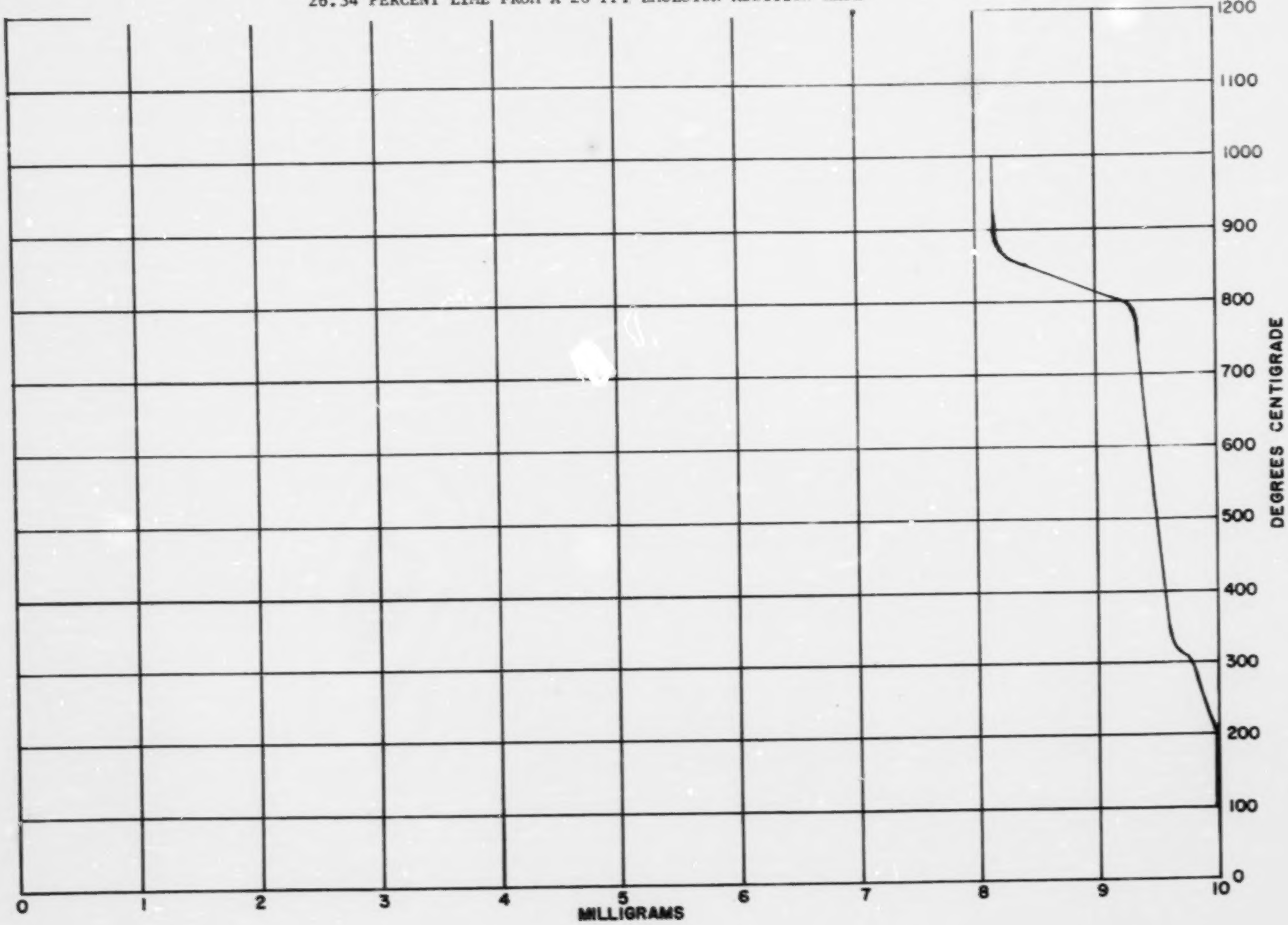


FIGURE 17D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 700038 THE $CT_8$ OF TEST 121 CONTAINING 29.45 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

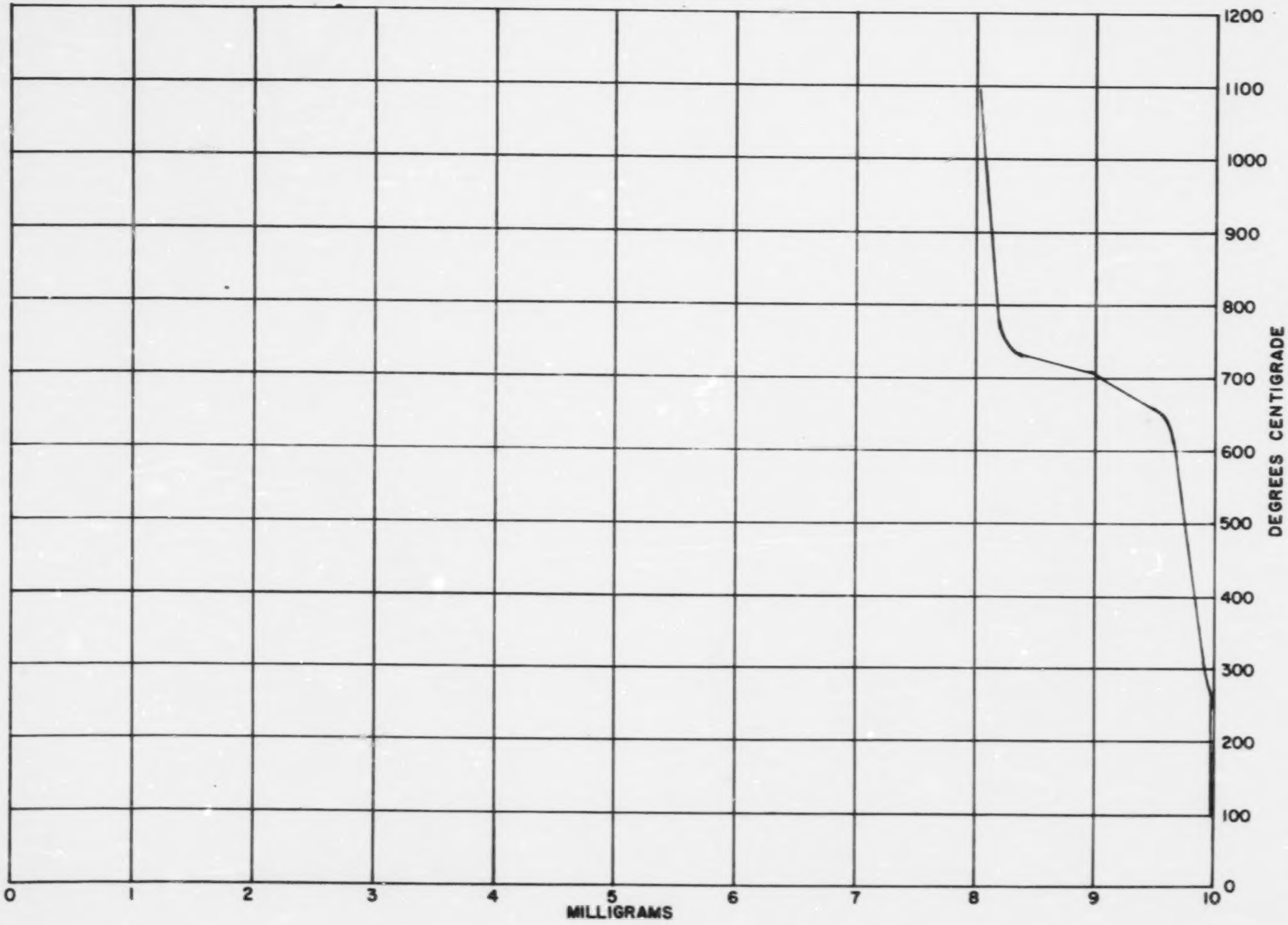


FIGURE 18D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690457 THE $CC_2$ OF TEST 96 CONTAINING 42.26 PERCENT LIME FROM A 60 PPT EMULSION ADDITION RATE

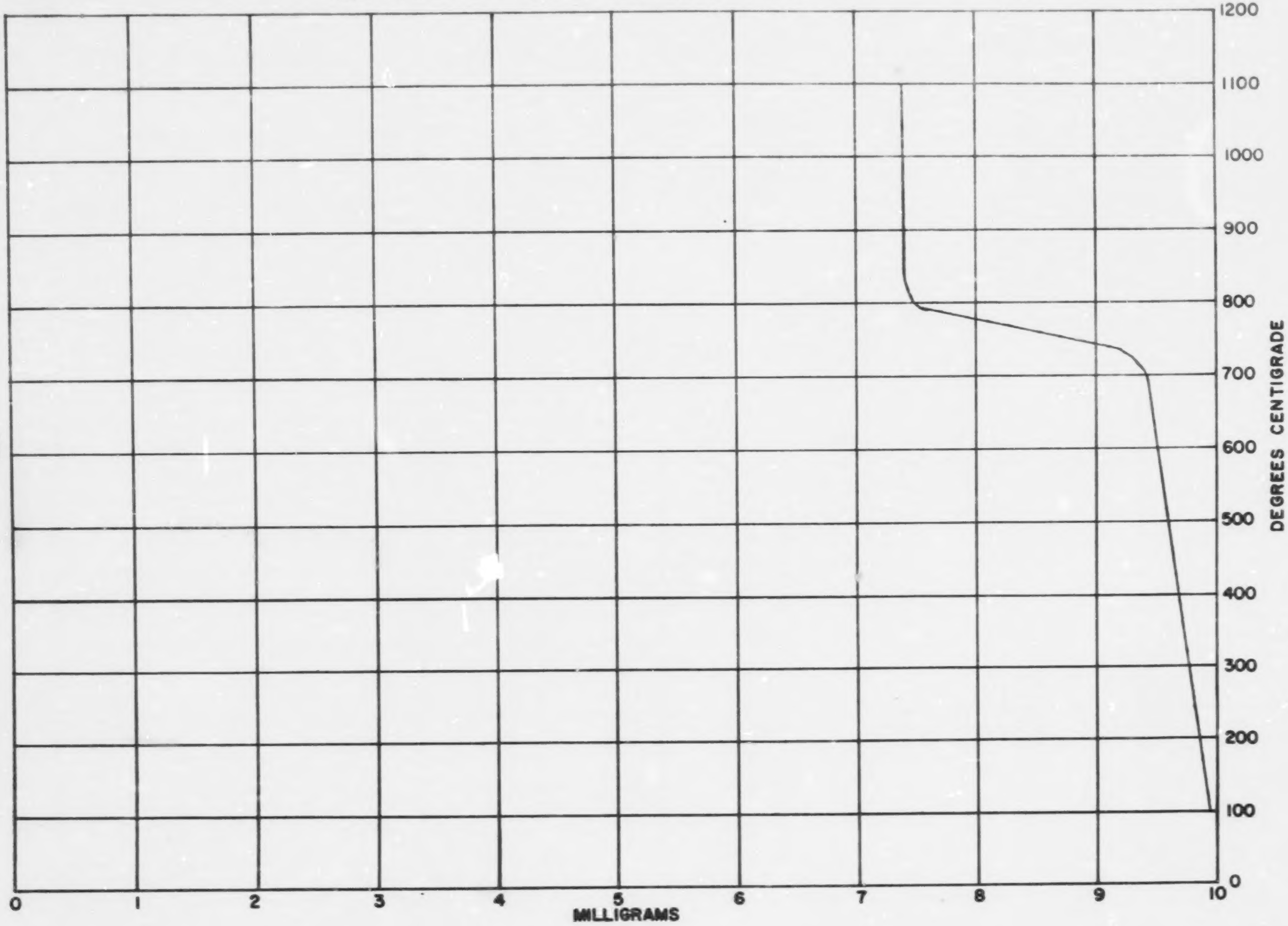


FIGURE 19D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690458 THE SC OF TEST 96 CONTAINING 34.04 PERCENT LIME FROM A 60 PPT EMULSION ADDITION RATE

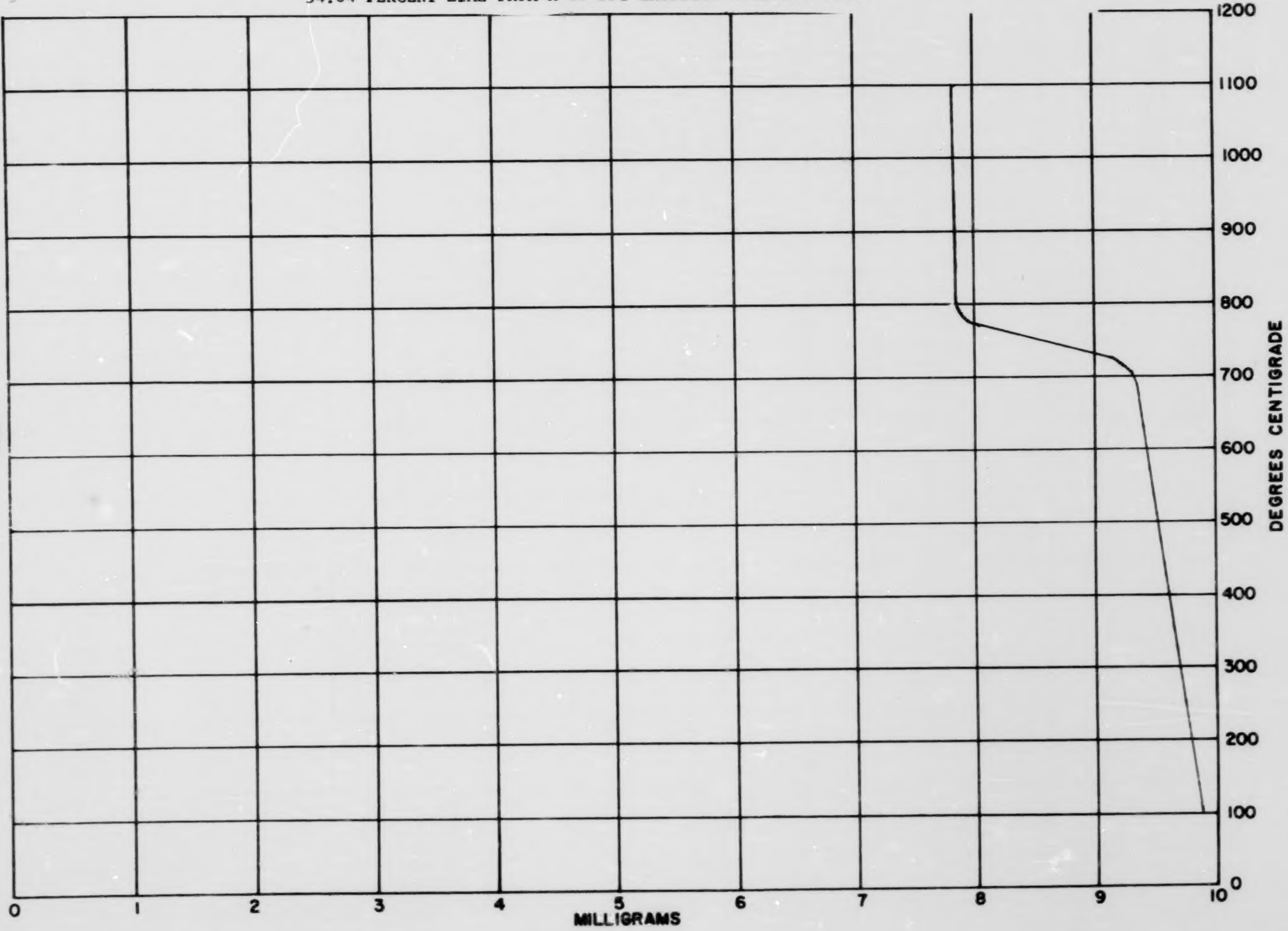


FIGURE 20D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690459 THE TT$_1$ OF TEST 96 CONTAINING 14.09 PERCENT LIME FROM A 60 PPT EMULSION ADDITION RATE

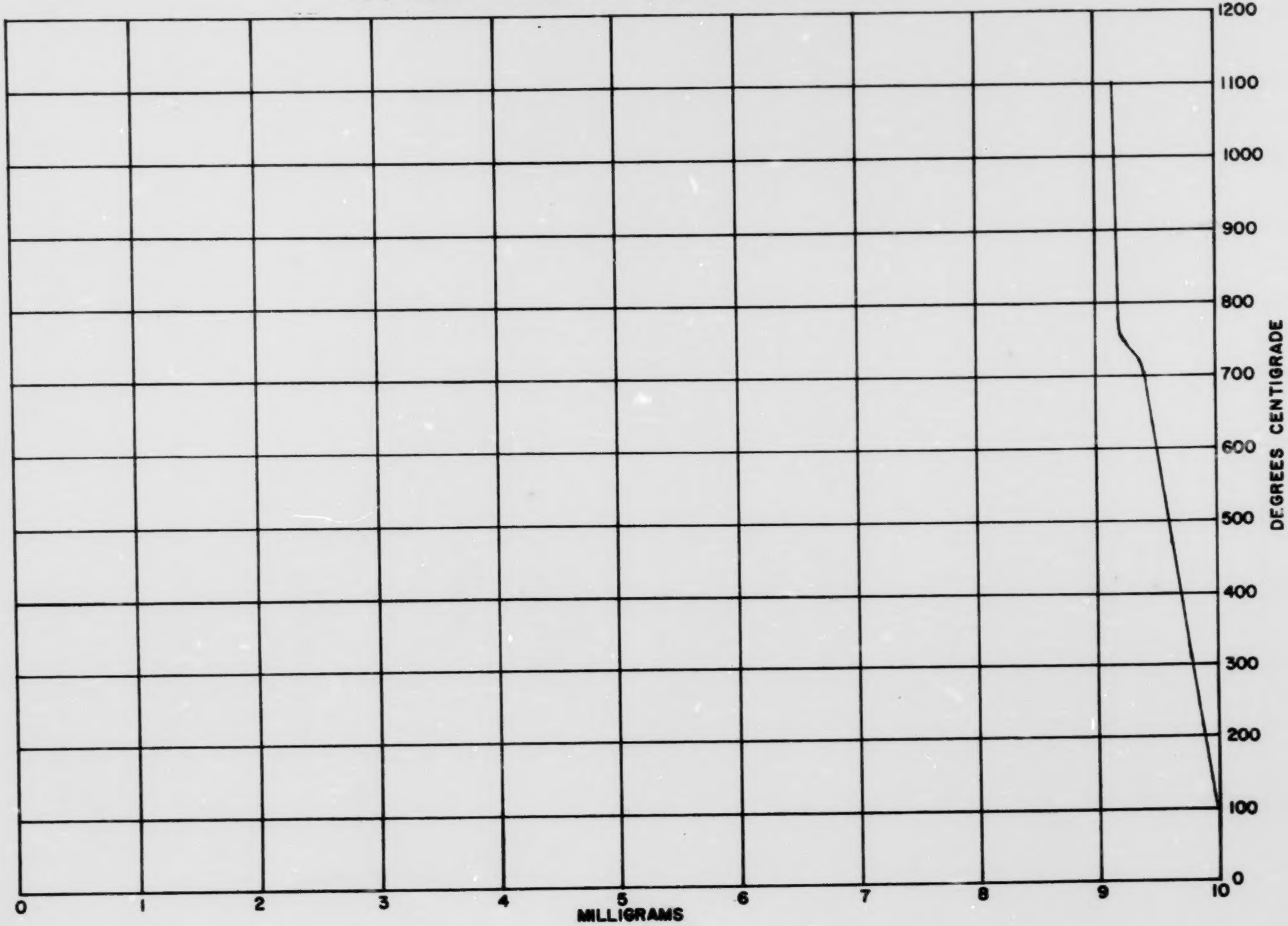


FIGURE 21D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690461 THE TT$_2$ OF TEST 96 CONTAINING 14.09 PERCENT LIME FROM A 60 PPT EMULSION ADDITION RATE

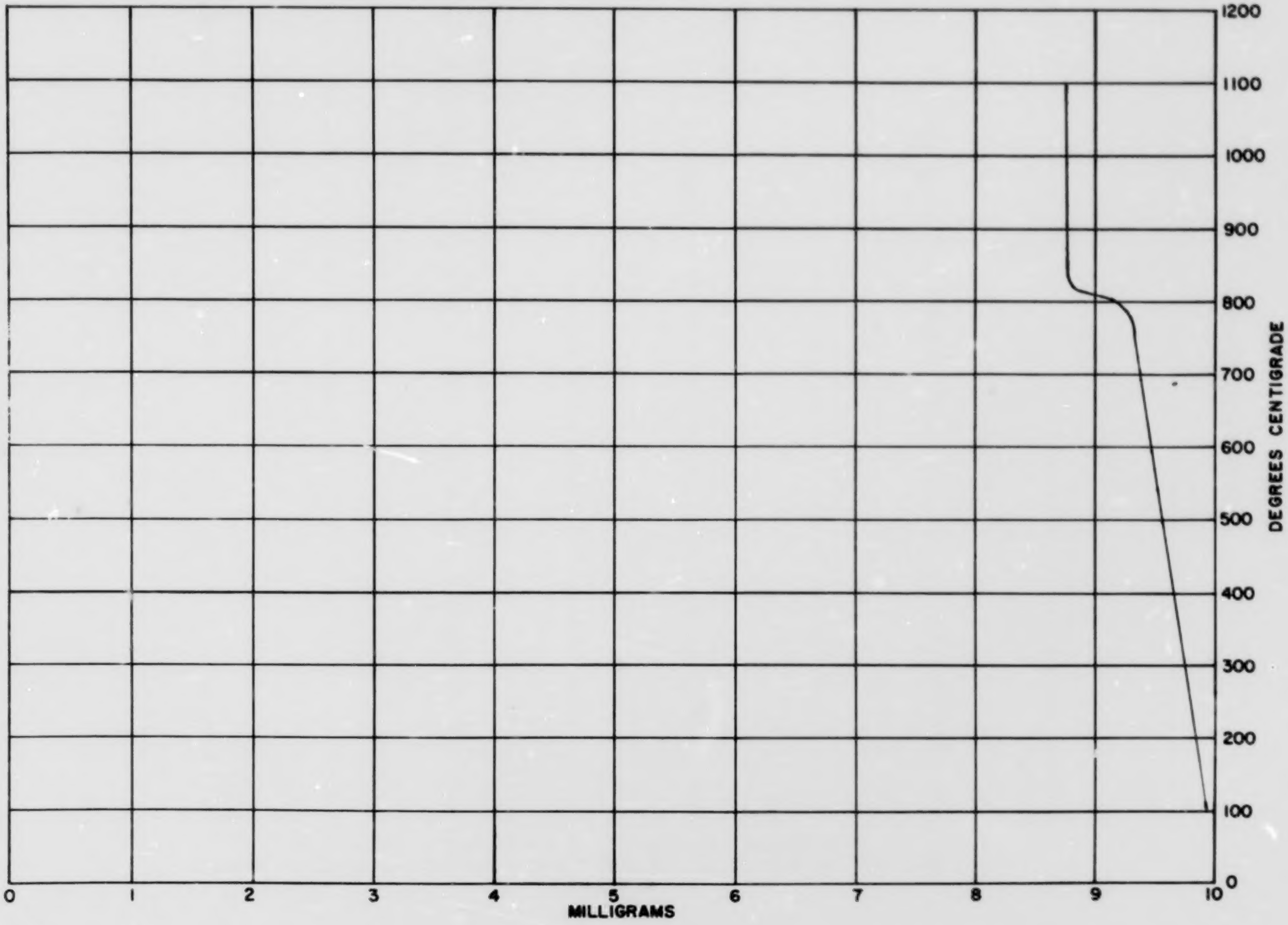


FIGURE 22D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690460 THE $TC_2$ OF TEST 96 CONTAINING
22.75 PERCENT LIME FROM A 60 PPT EMULSION ADDITION RATE

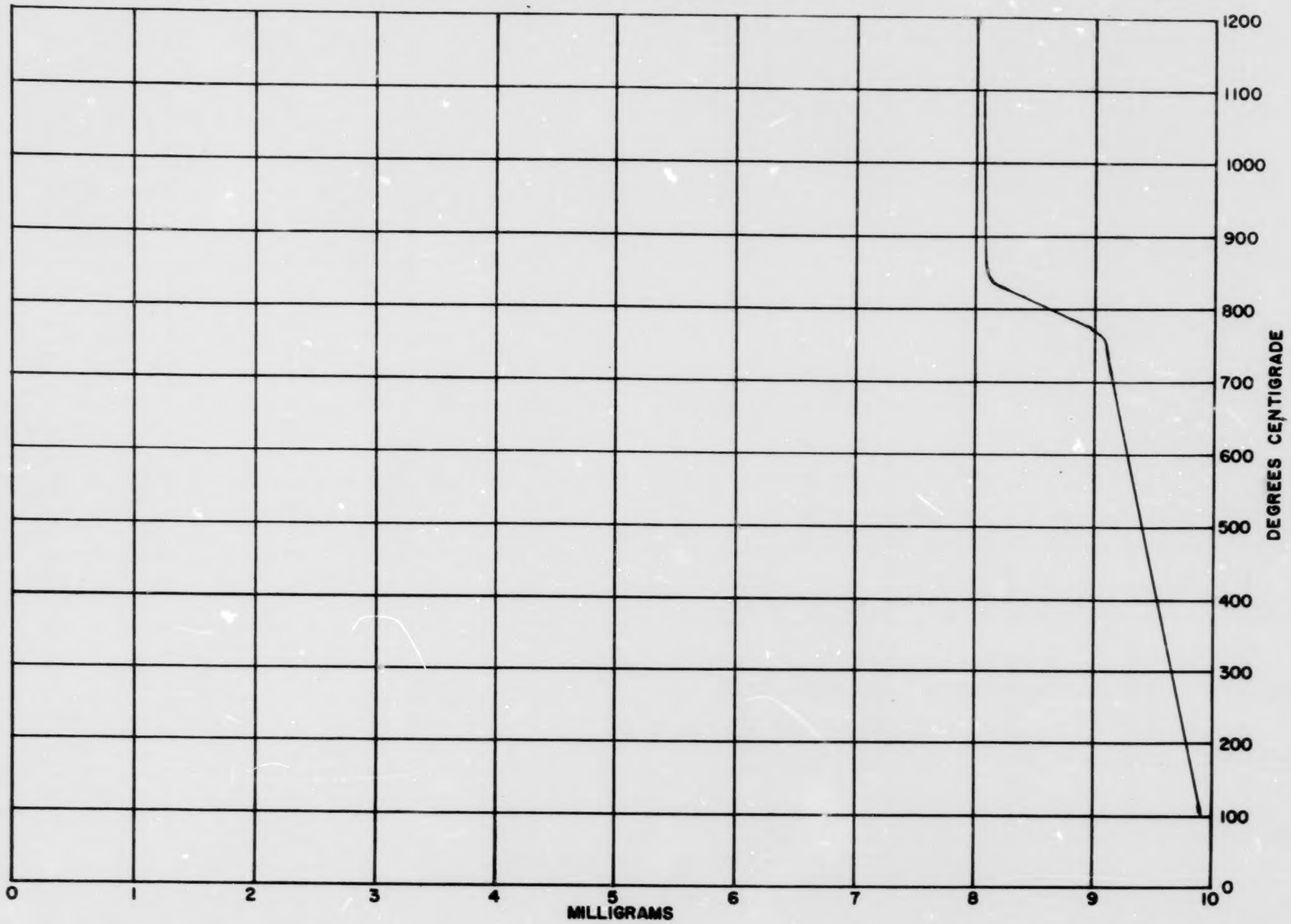


FIGURE 23D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690452 CC$_2$ OF TEST 95 CONTAINING
11.30 PERCENT LIME FROM A 60 PPT EMULSION ADDITION RATE

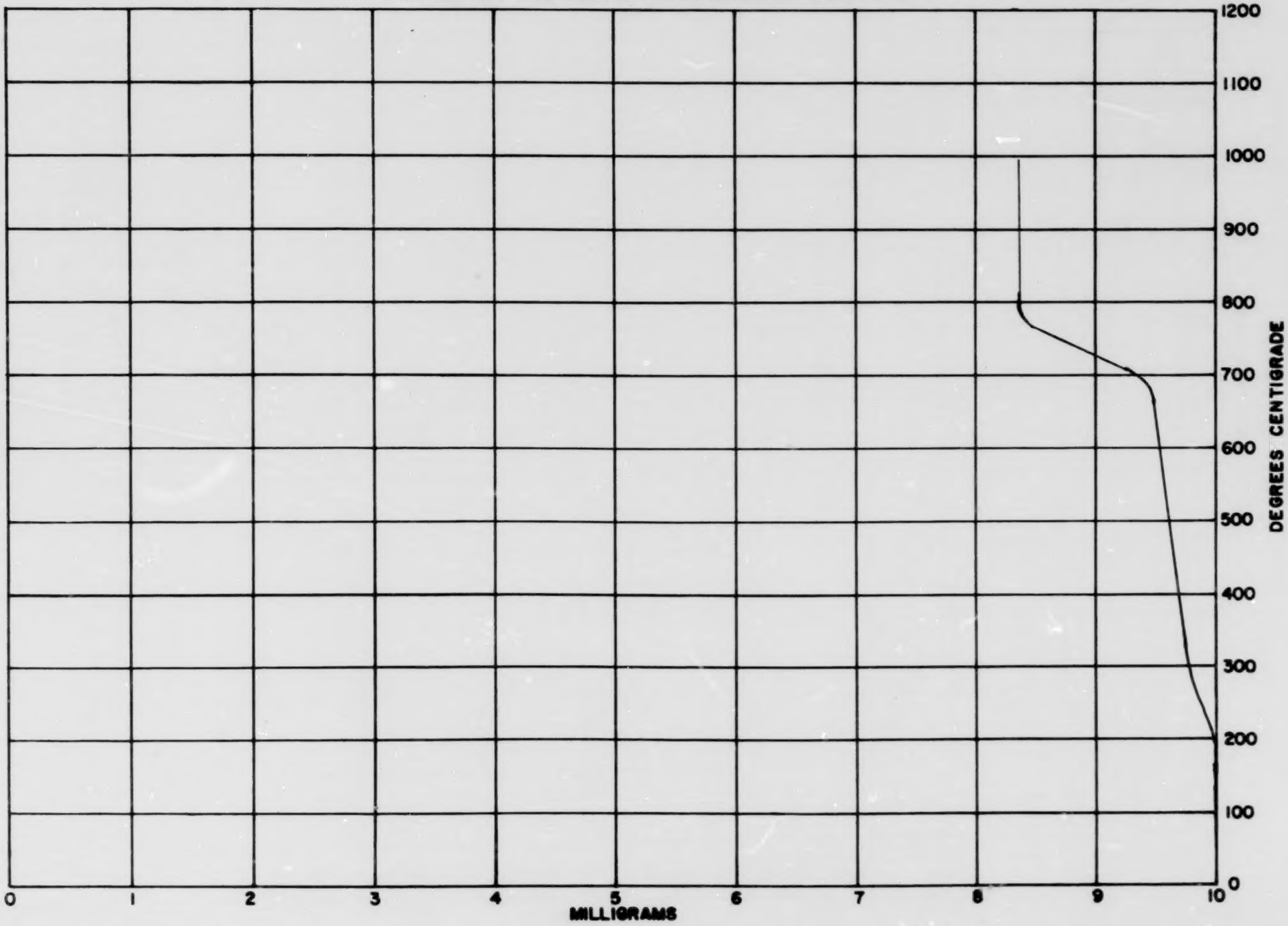


FIGURE 24D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690453 THE SC OF TEST 95 CONTAINING
34.43 PERCENT LIME FROM A 60 PPT EMULSION ADDITION RATE

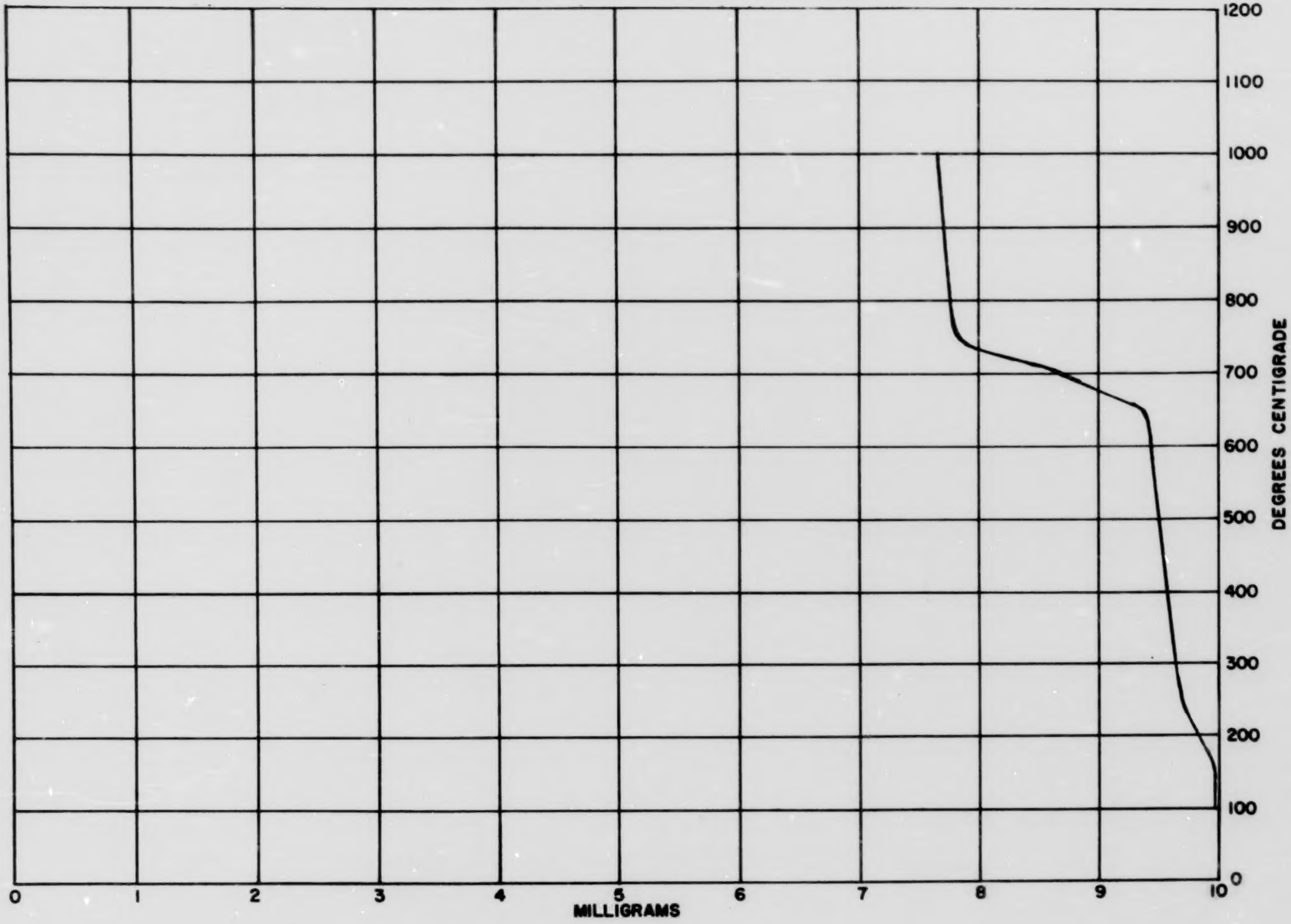


FIGURE 25D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690454 THE TT$_1$ OF TEST 95 CONTAINING 32.38 PERCENT LIME FROM A 60 PPT EMULSION ADDITION RATE

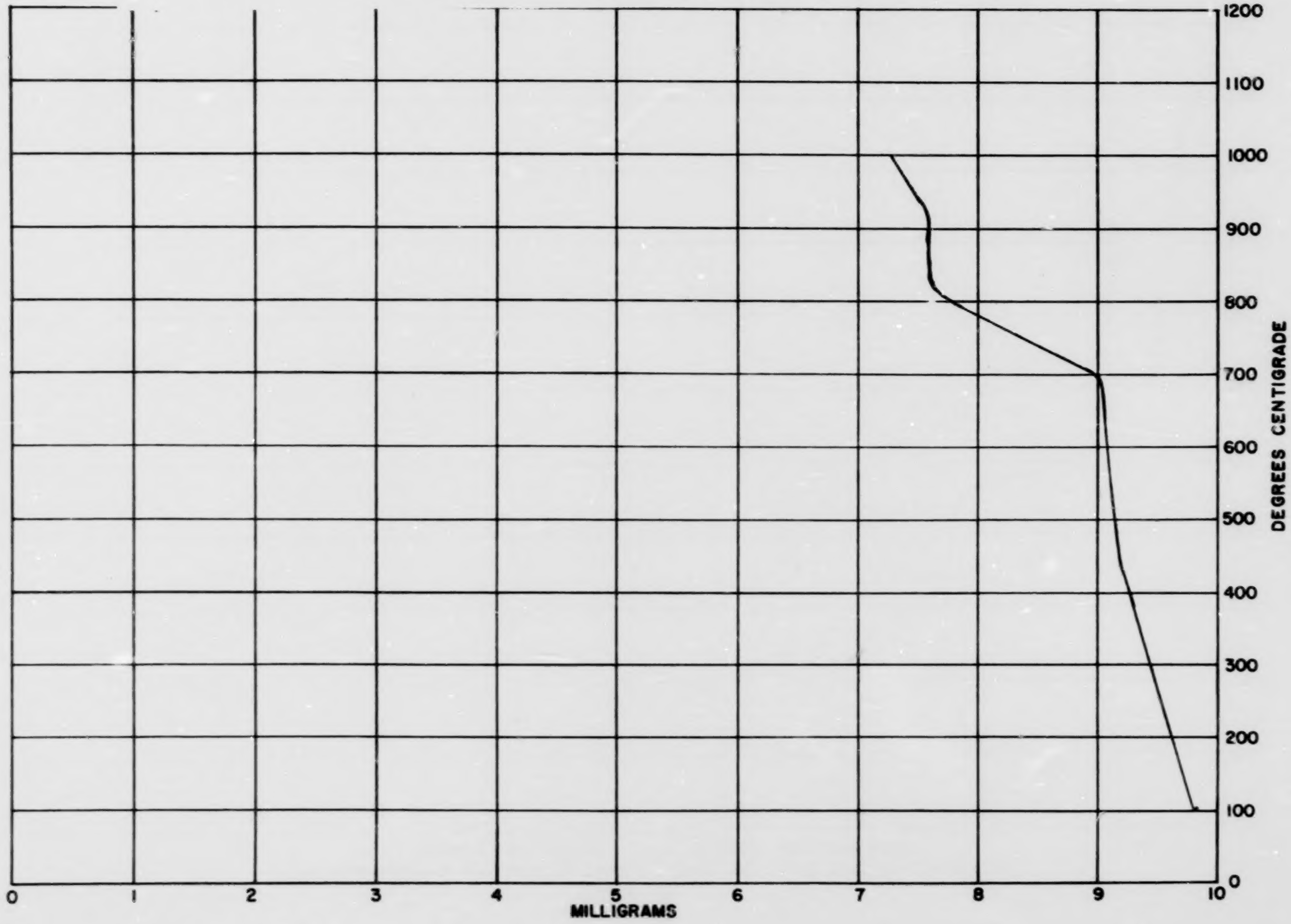


FIGURE 26D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690456 THE $TT_2$ OF TEST 95 CONTAINING
32.72 PERCENT LIME FROM A 60 PPT EMULSION ADDITION RATE

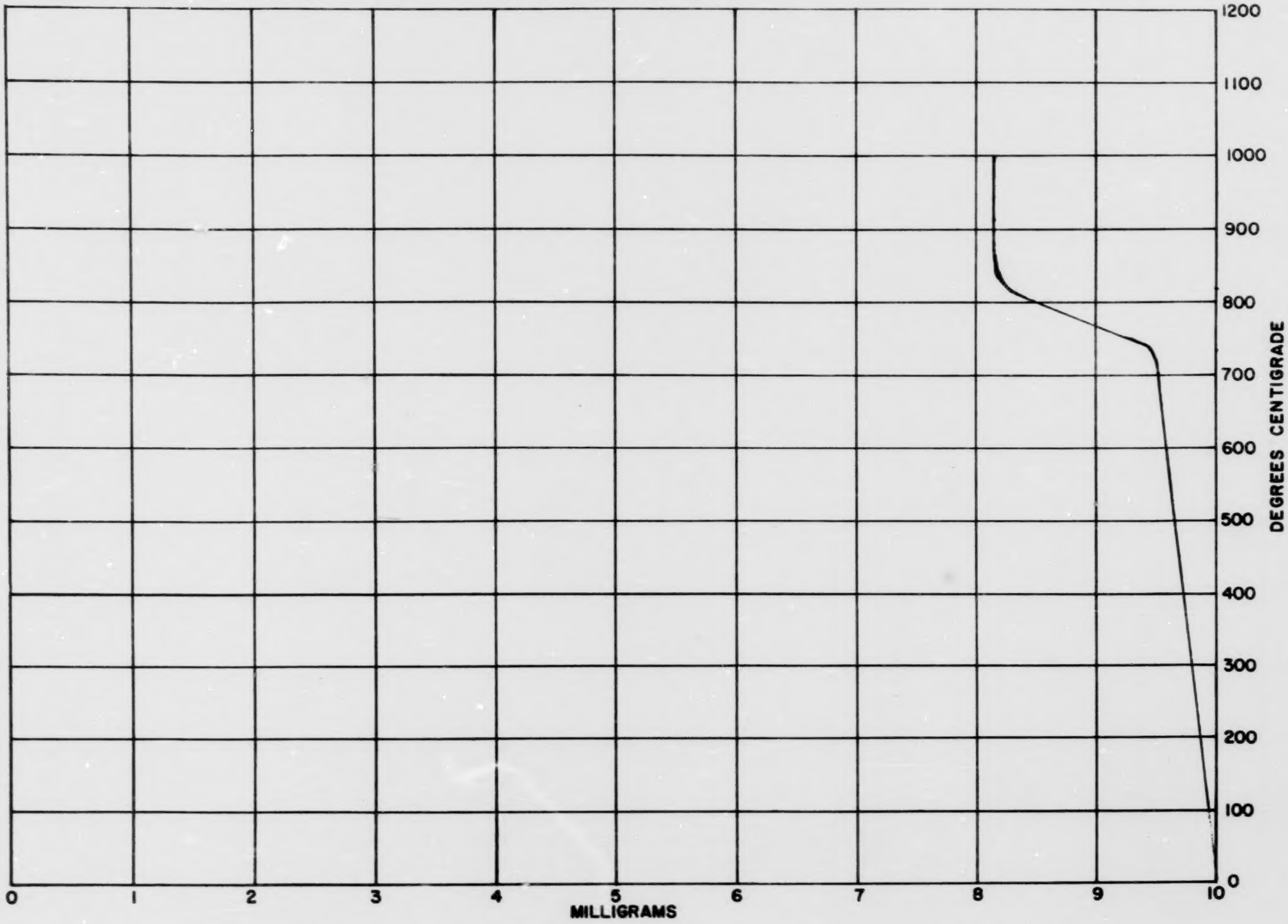


FIGURE 27D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690455 THE $TC_2$ OF TEST 95 CONTAINING 25.46 PERCENT LIME FROM A 60 PPT EMULSION ADDITION RATE

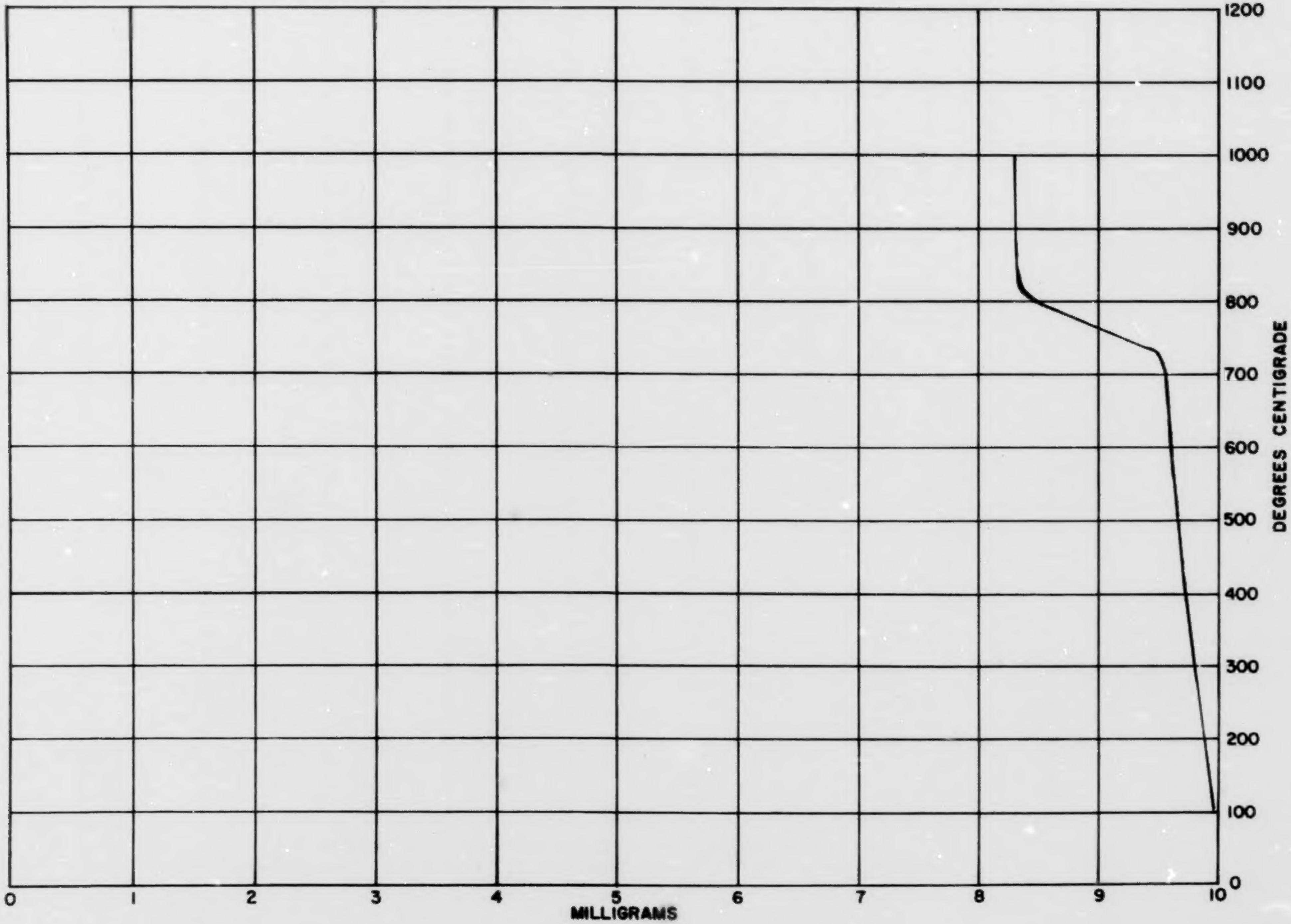


FIGURE 28D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 681049 THE $CC_1$ OF TEST 73 CONTAINING 48.74 PERCENT LIME FROM A 112.6 PPT EMULSION ADDITION RATE

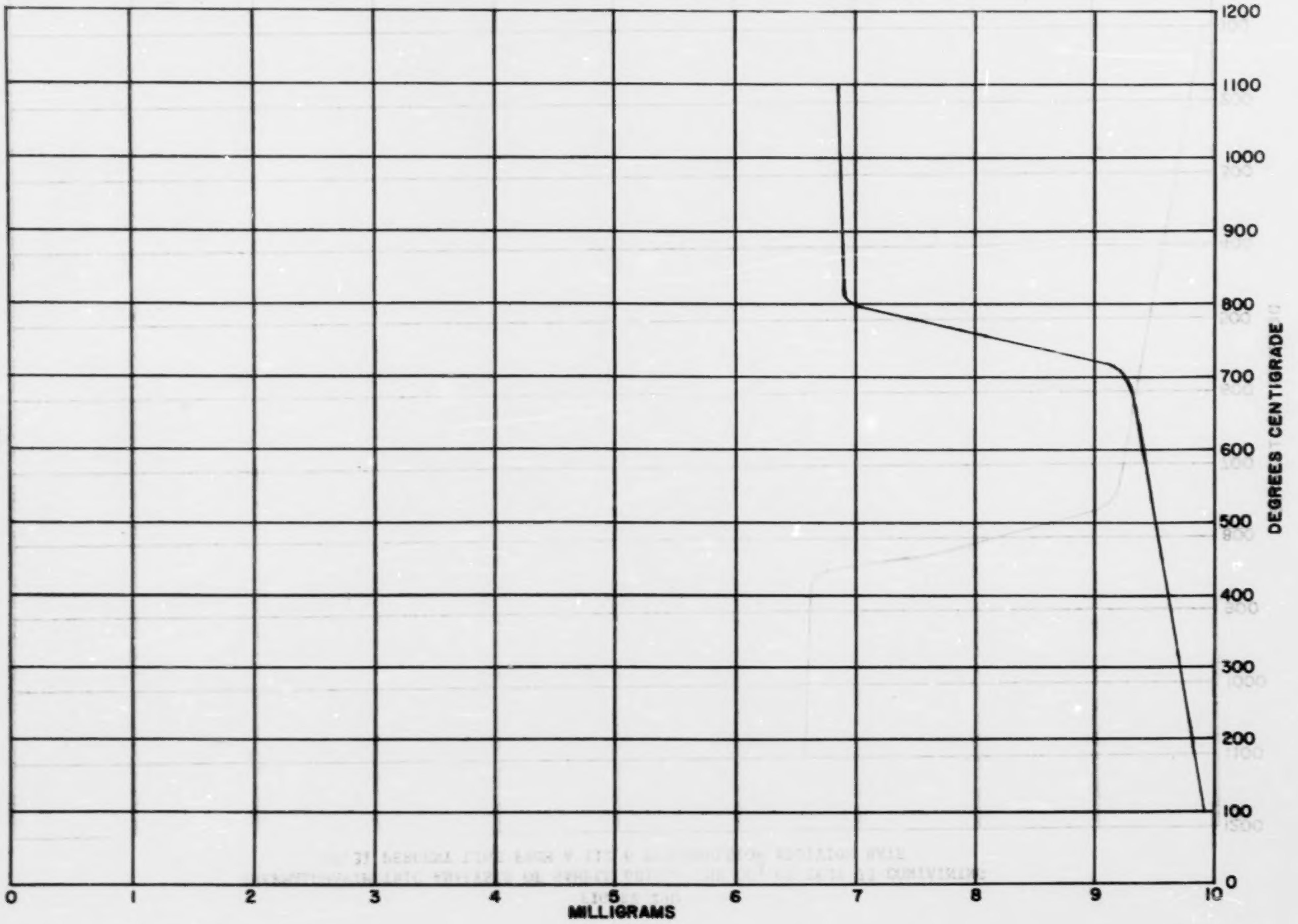


FIGURE 29D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 681051 THE $CC_3$ OF TEST 73 CONTAINING 50.31 PERCENT LIME FROM A 112.6 PPT EMULSION ADDITION RATE

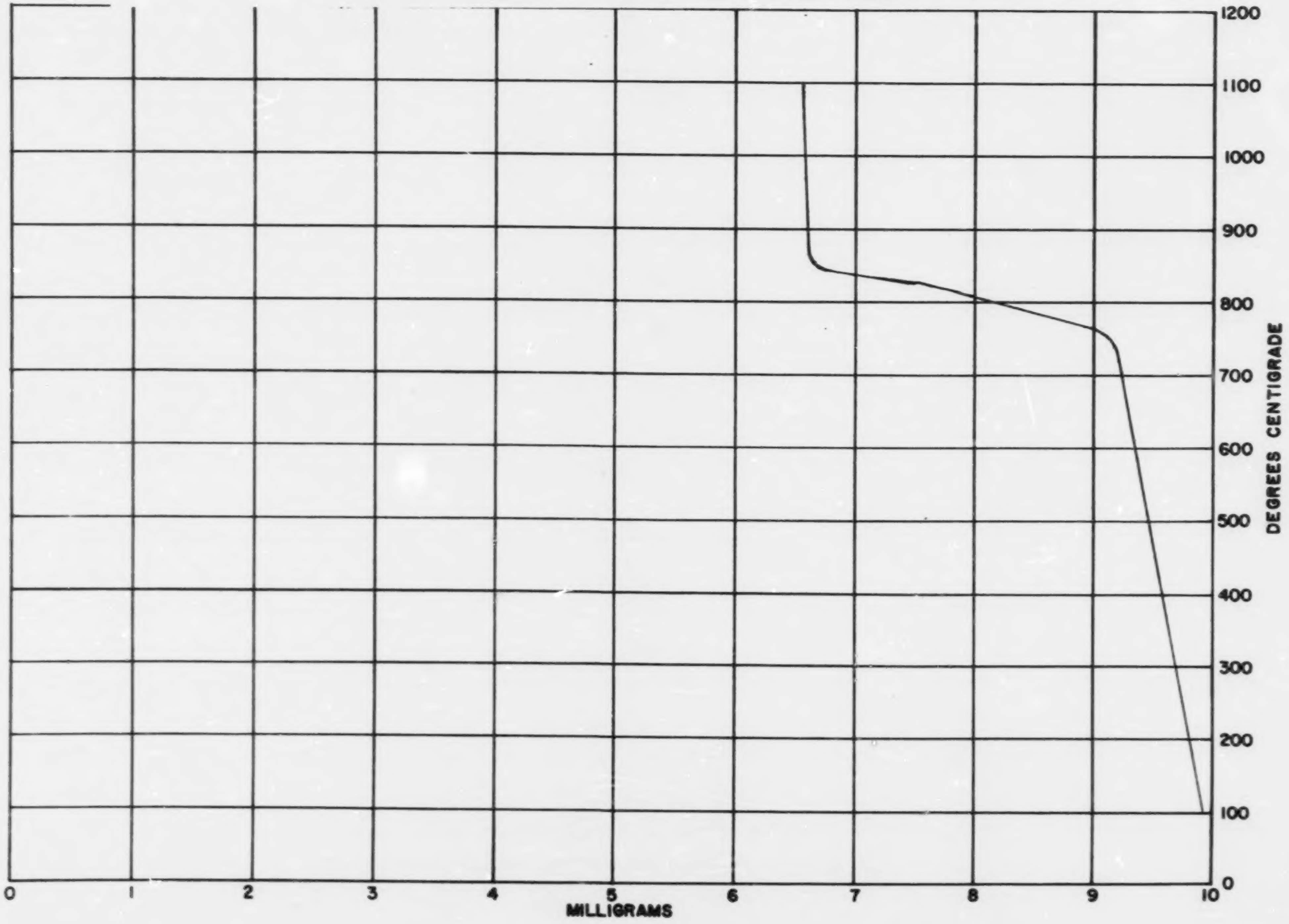


FIGURE 30D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690310 THE $CC_3$ OF TEST 84 CONTAINING 51.27 PERCENT LIME FROM A 1:2.6 PPT EMULSION ADDITION RATE

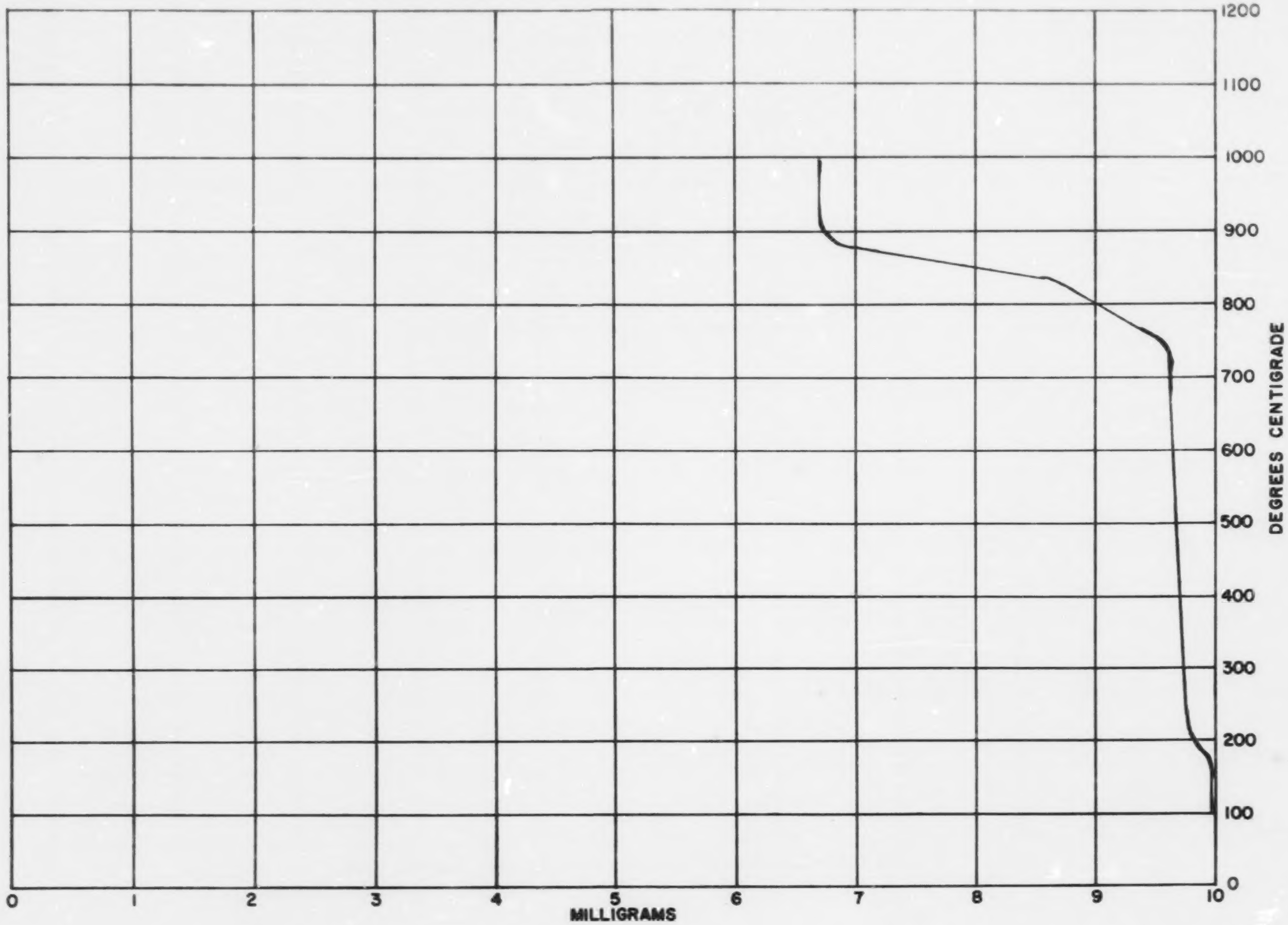


FIGURE 31D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690308 THE $CT_1$ OF TEST 84 CONTAINING 26.82 PERCENT LIME FROM A 112.6 PPT EMULSION ADDITION RATE

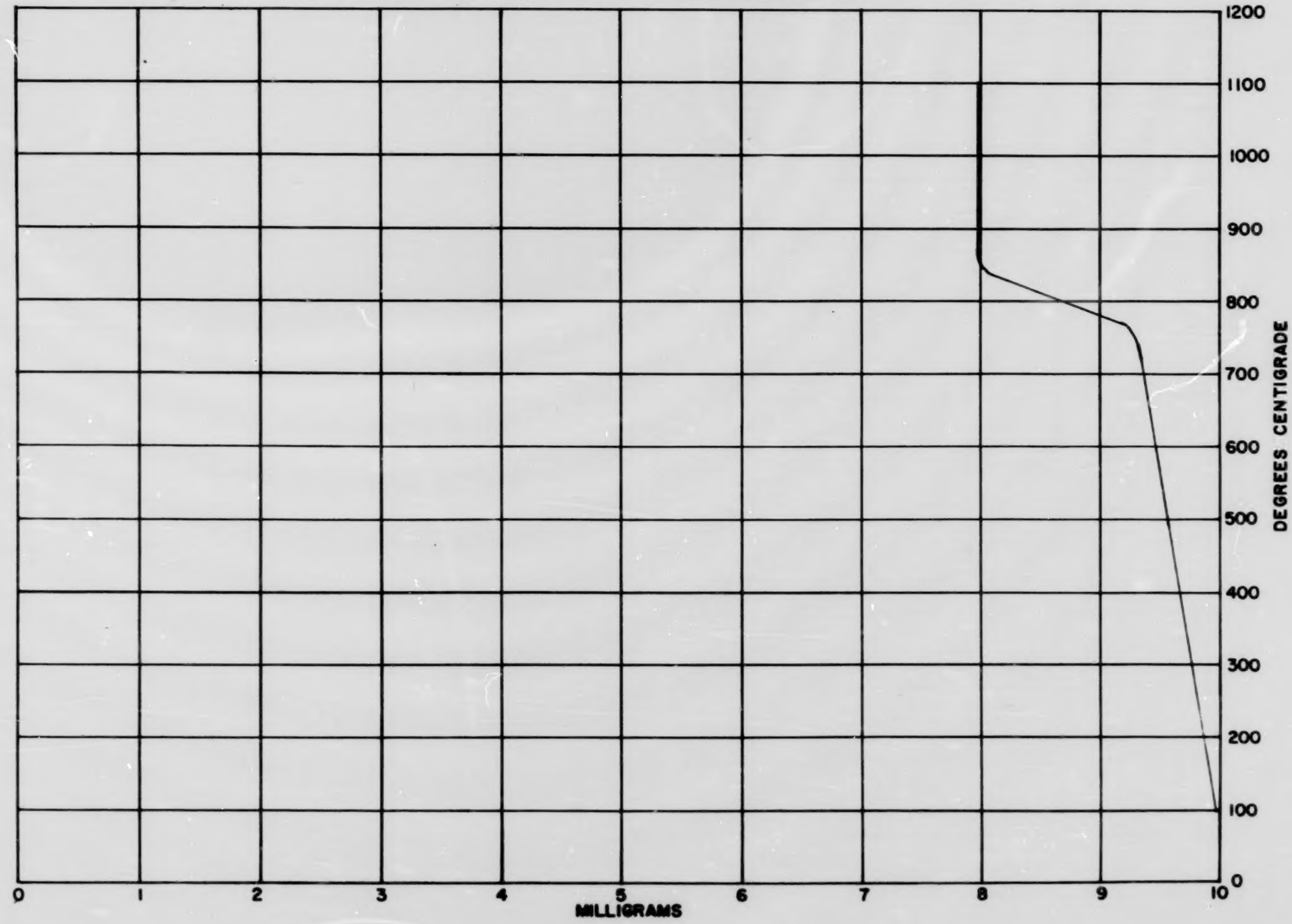
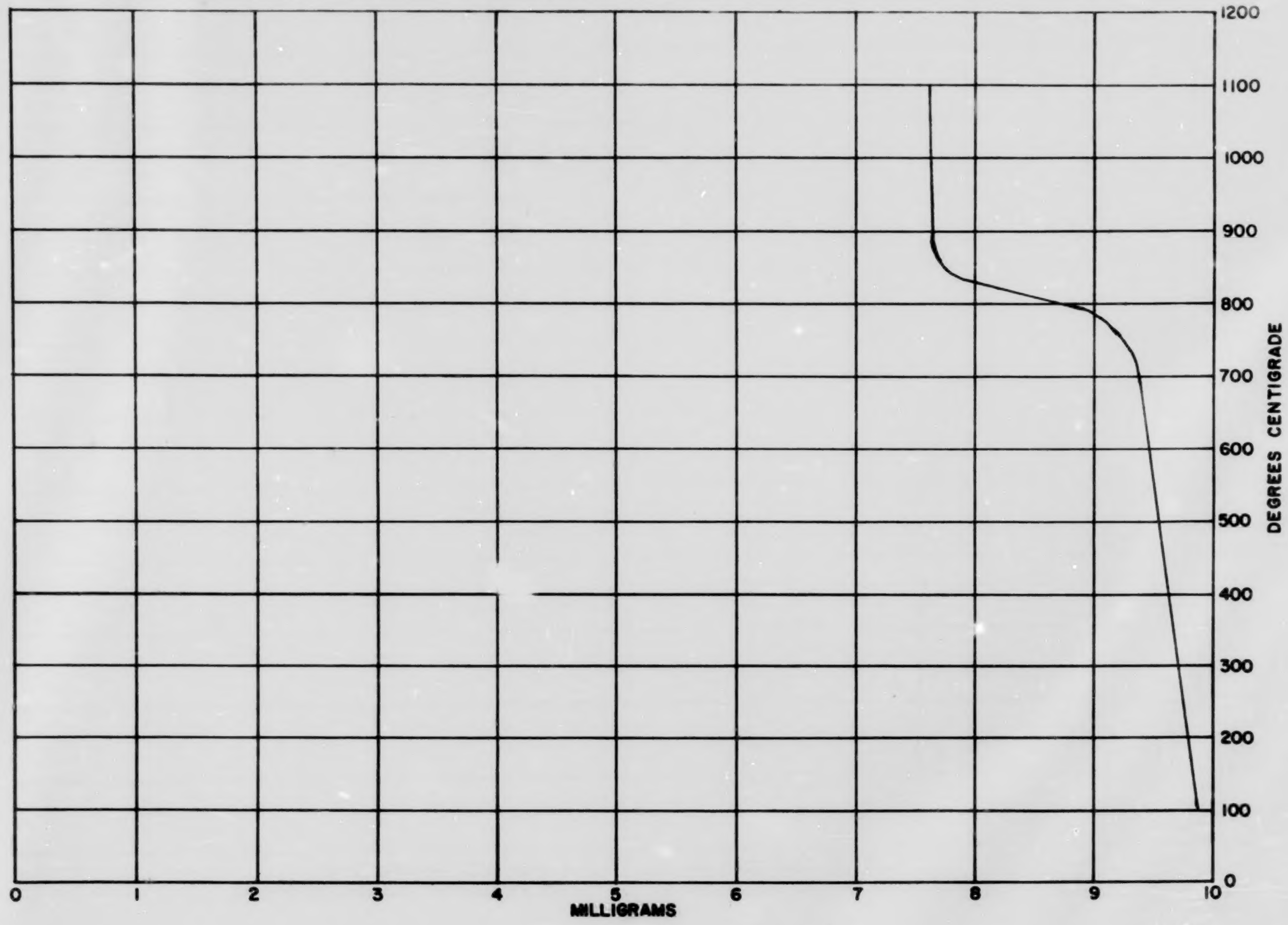


FIGURE 32D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690309 THE $CT_2$ OF TEST 84 CONTAINING 32.29 PERCENT LIME FROM A 112.6 PPT EMULSION ADDITION RATE



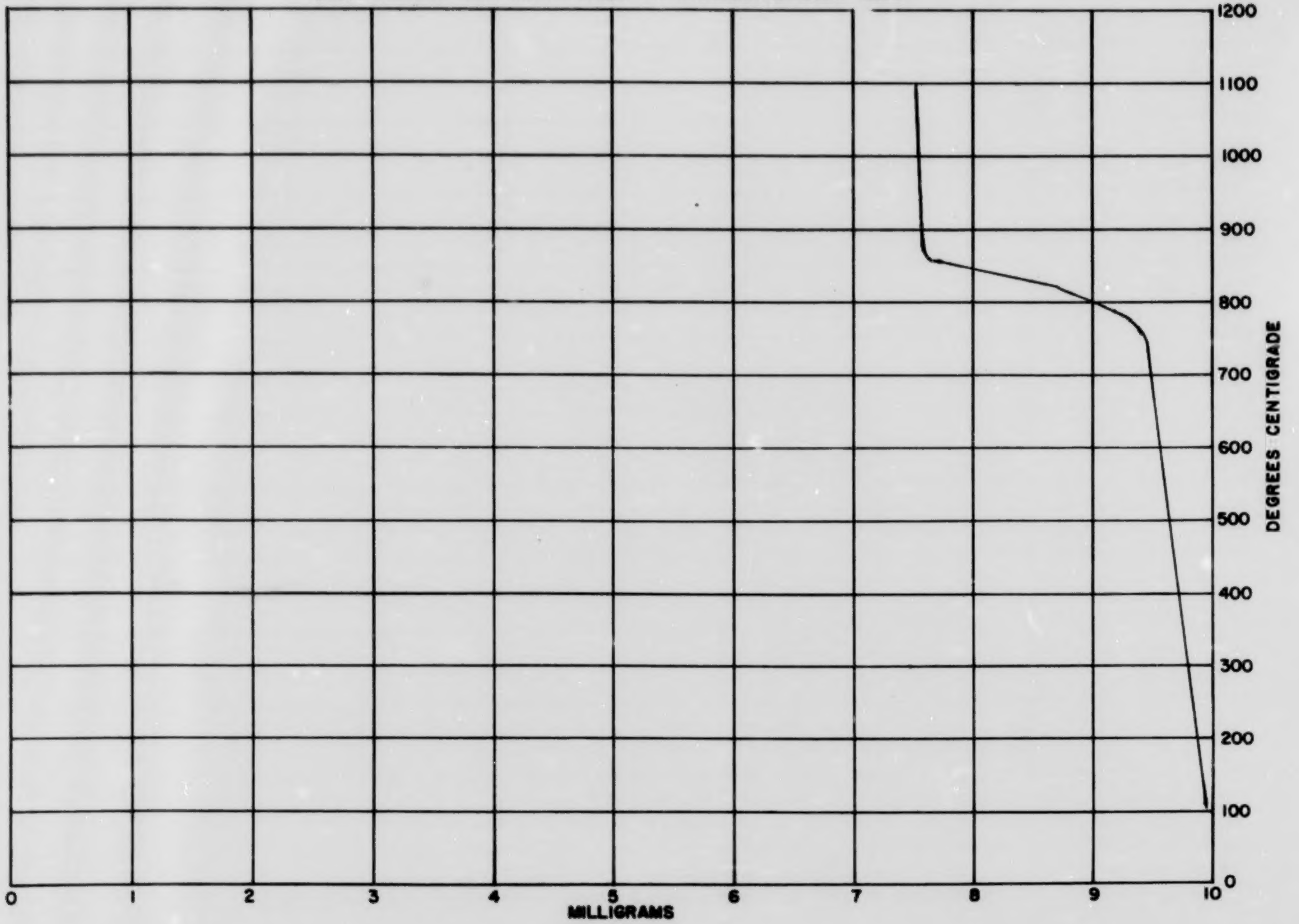


FIGURE 33D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690311 THE $CT_3$ OF TEST 84 CONTAINING 34.53 PERCENT LIME FROM A 112.6 PPT EMULSION ADDITION RATE

FIGURE 34D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690312 THE RT OF TEST 84 CONTAINING 20.26 PERCENT LIME FROM A 112.6 PPT EMULSION ADDITION RATE

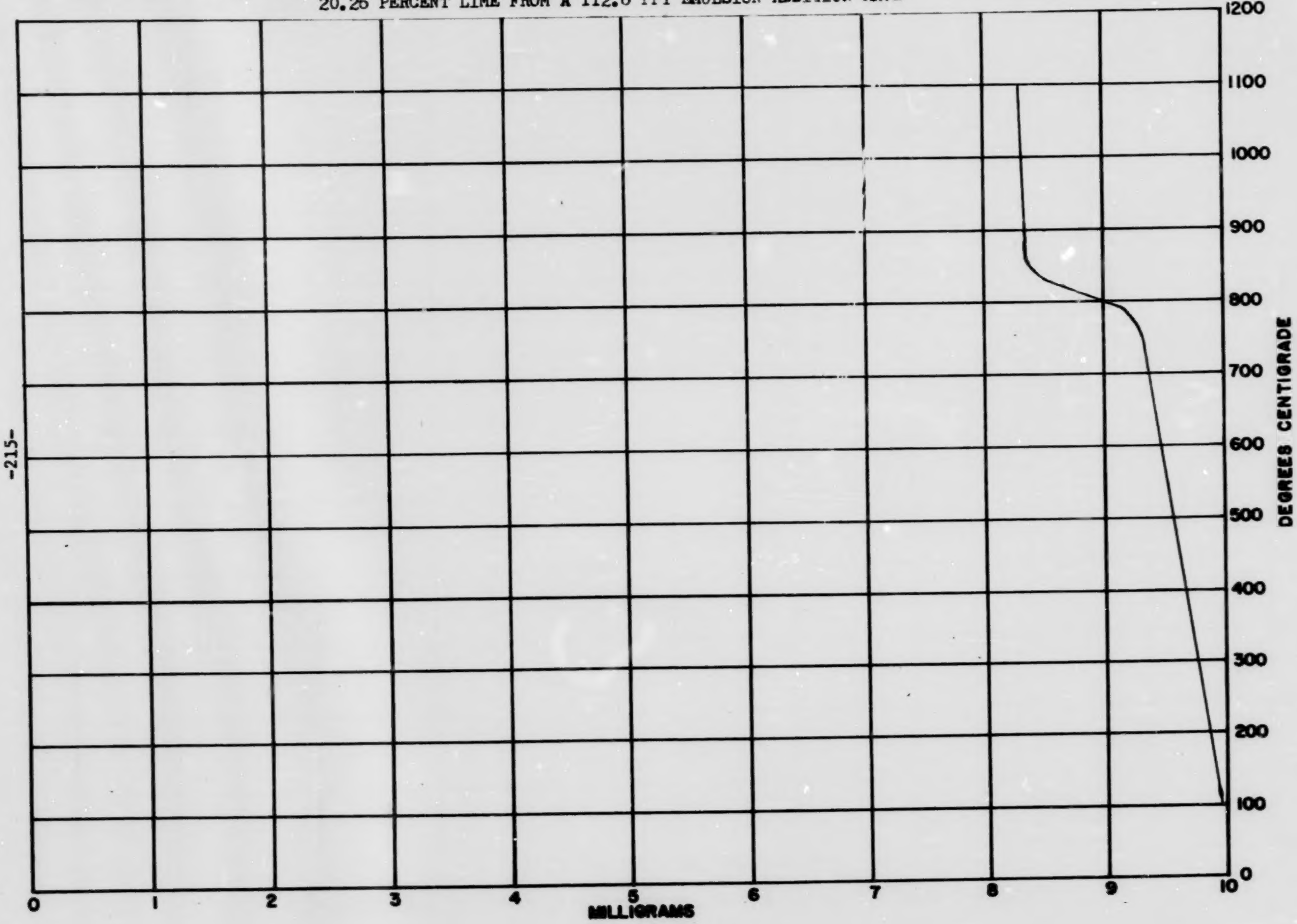


FIGURE 35D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690230 THE $CC_1$ OF THE 1st 5 MINUTES FLOTATION OF TEST 82 CONTAINING 29.93 PERCENT LIME FROM A 112.6 PPT EMULSION ADDITION RATE

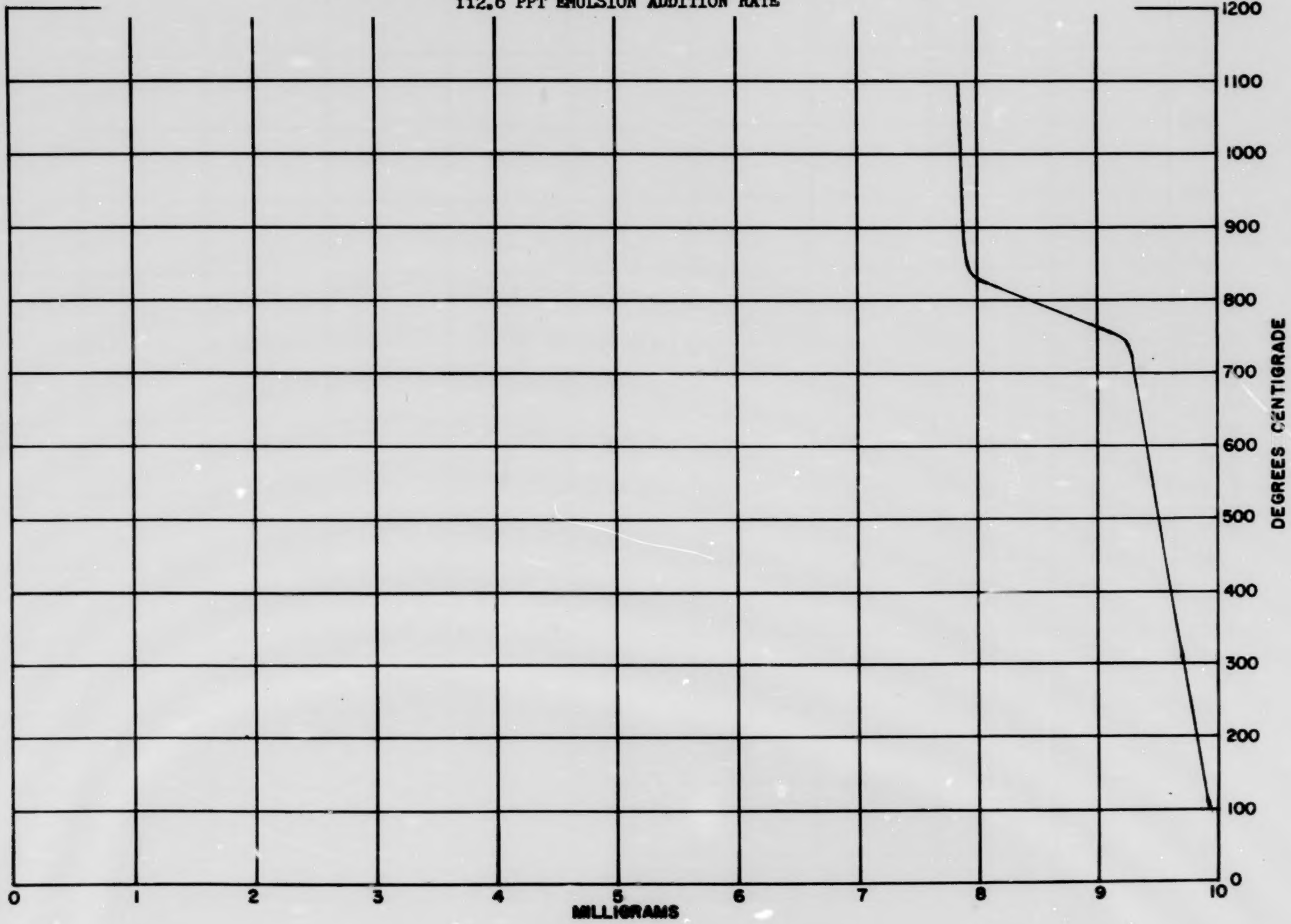


FIGURE 36D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690232 THE CC$_3$ OF THE 1st 5 MINUTES FLOTATION OF TEST 82 CONTAINING 28.18 PERCENT LIME FROM A 112.6 PPT EMULSION ADDITION RATE

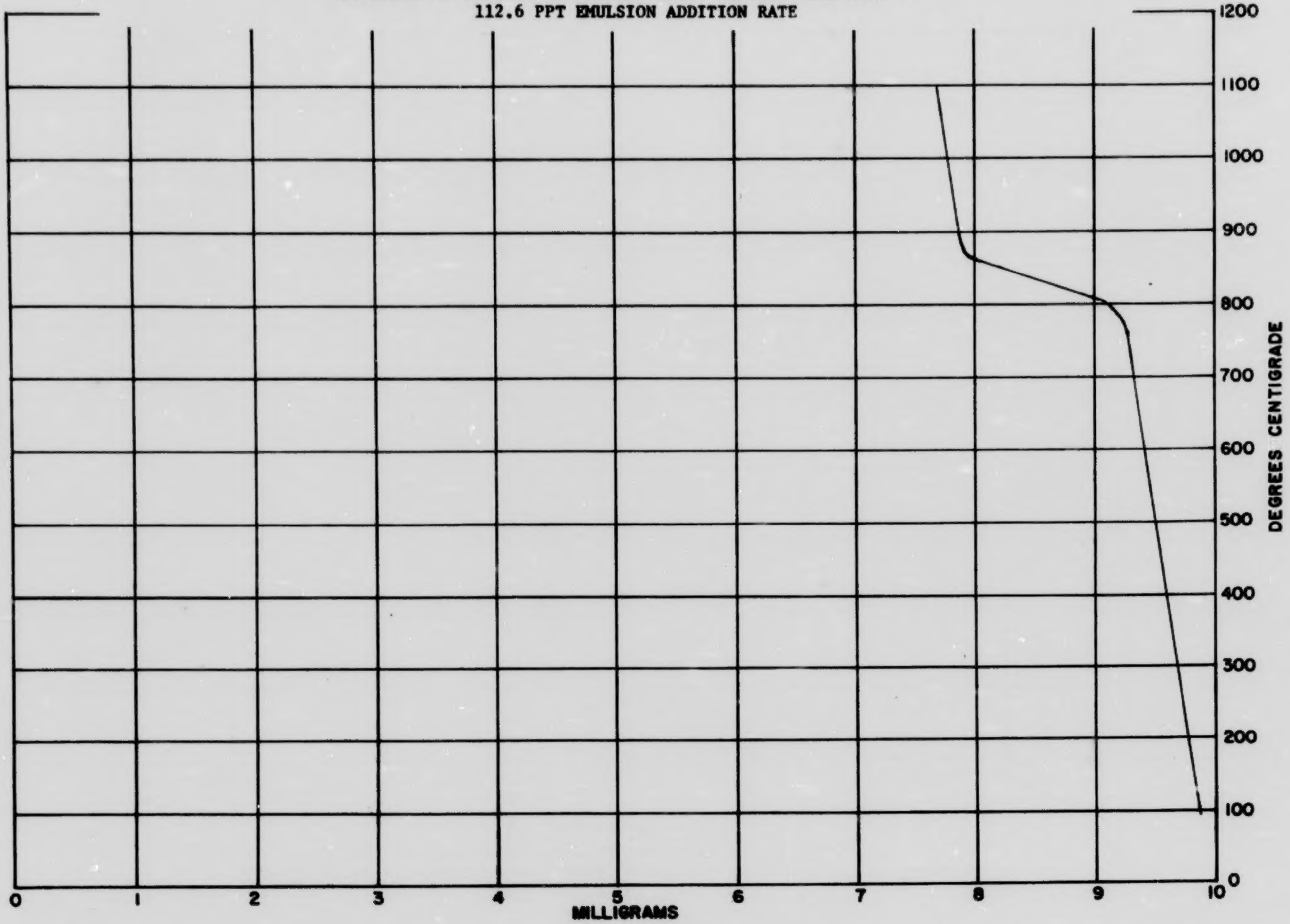


FIGURE 37D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690234 THE 2nd 5 MINUTES RC FLOTATION OF TEST 82 CONTAINING 26.30 PERCENT LIME FROM A 112.6 PPT EMULSION ADDITION RATE

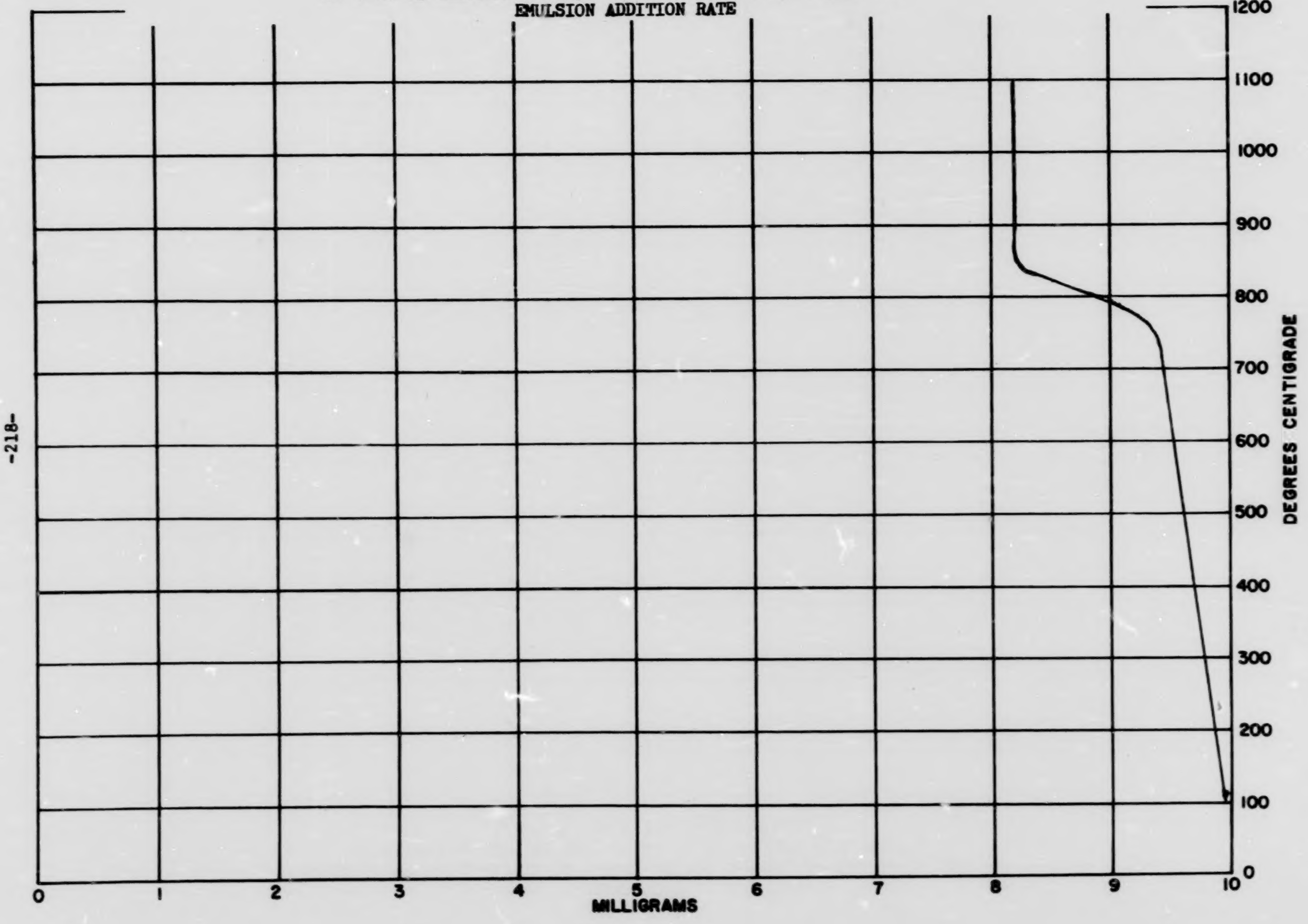


**FIGURE 38D**

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690363 THE RT OF TEST 85 CONTAINING
19.69 PERCENT LIME FROM A 140.8 PPT EMULSION ADDITION RATE

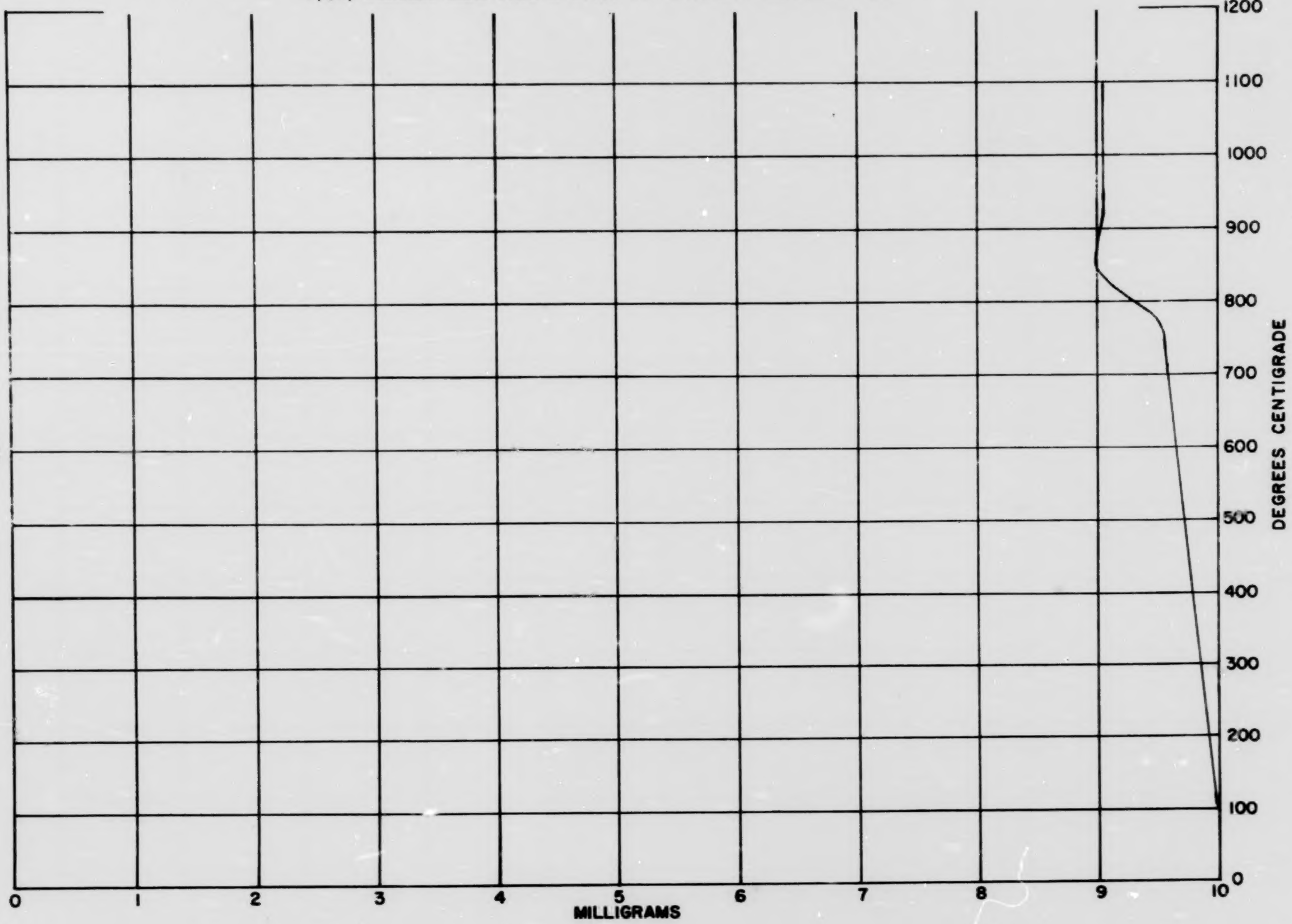


FIGURE 39D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690366 THE CT-1 OF TEST 85 CONTAINING
30.56 PERCENT LIME FROM A 140.8 PPT EMULSION ADDITION RATE

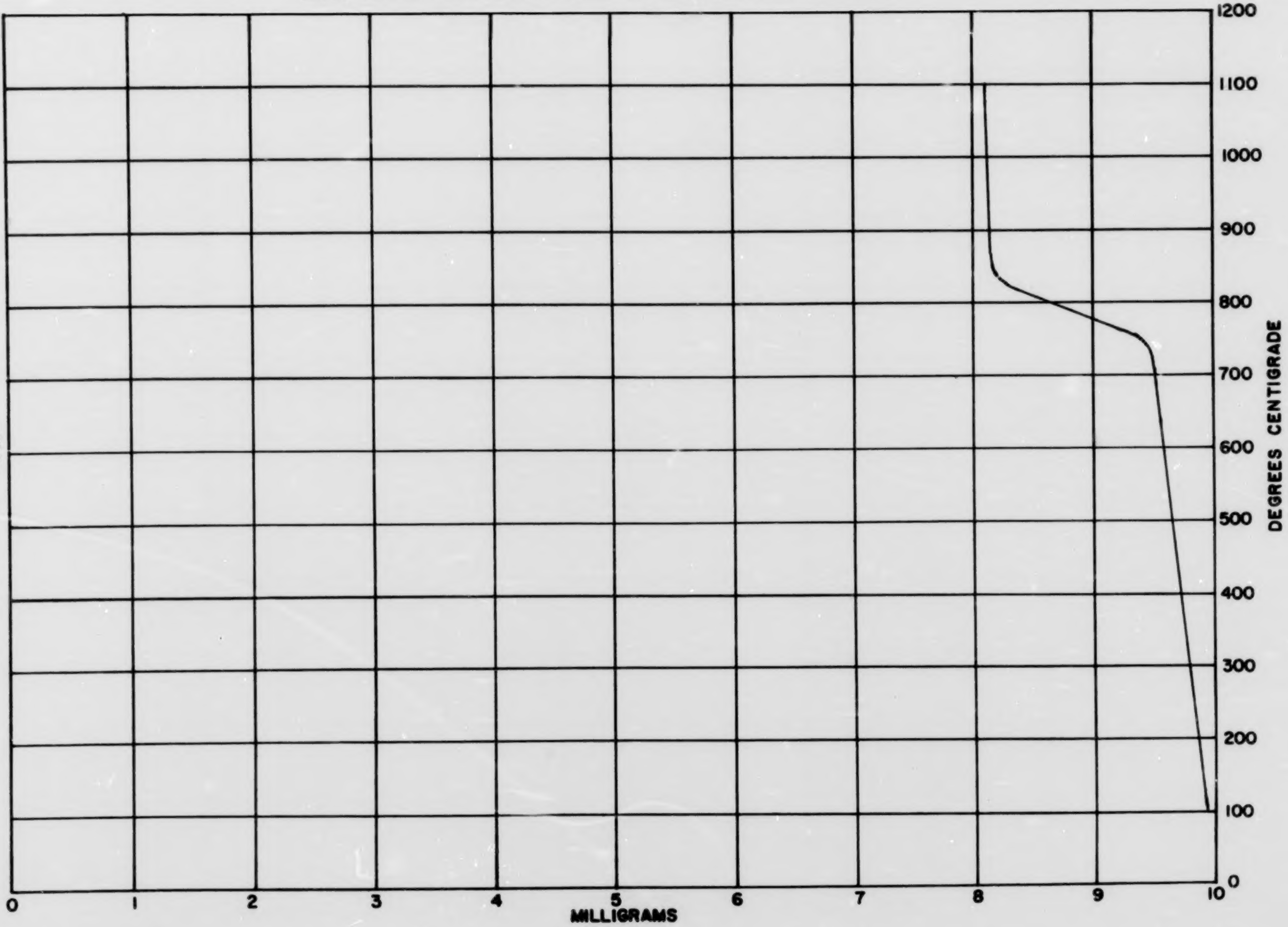


FIGURE 40D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690364 THE RC$_1$ OF TEST 85 CONTAINING 51.27 PERCENT LIME FROM A 140.70 PPT EMULSION ADDITION RATE

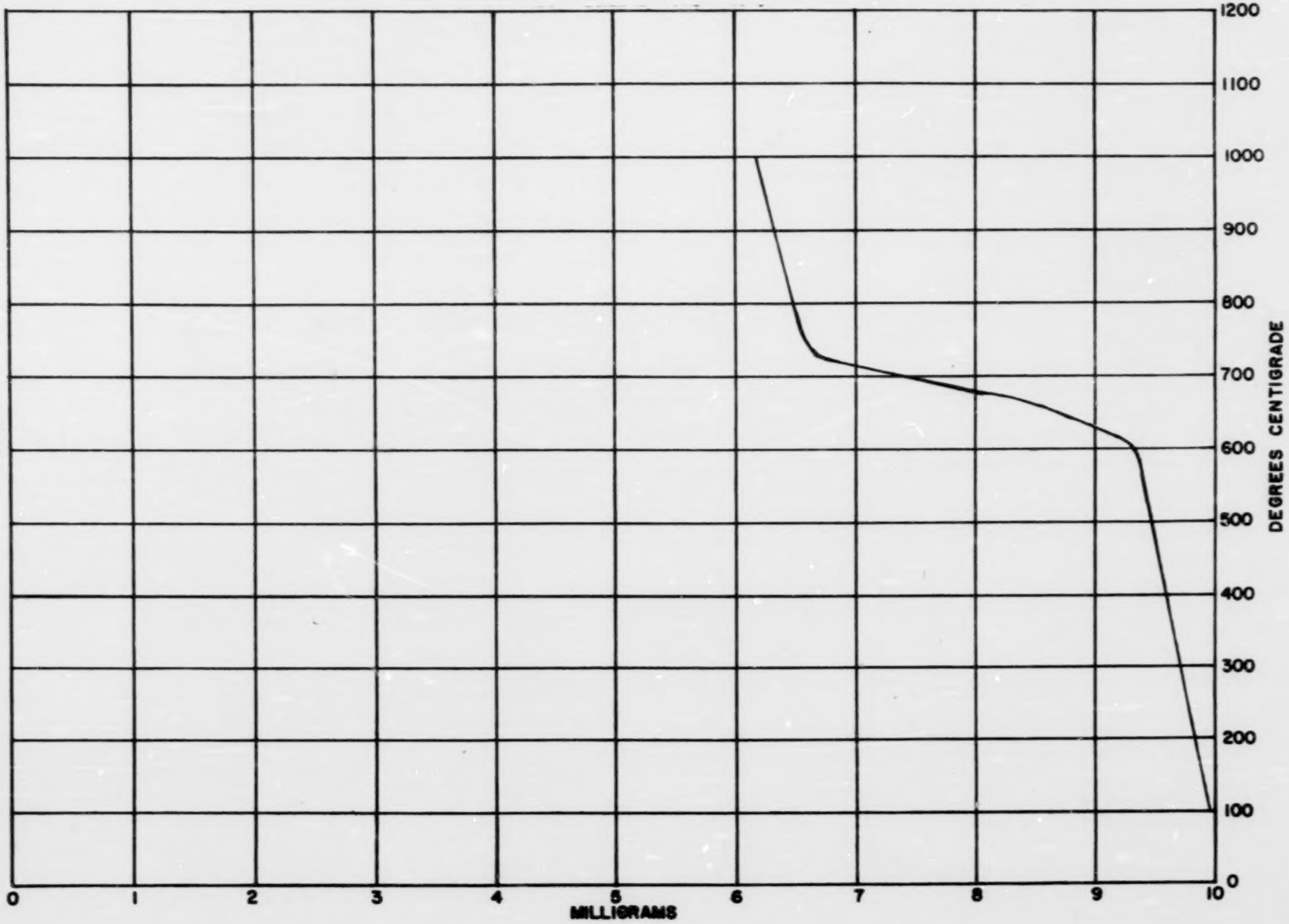


FIGURE 41D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690365 THE RC SECOND FRACTION OF TEST 85 CONTAINING 44.76 PERCENT LIME FROM A 140.70 PPT EMULSION ADDITION RATE

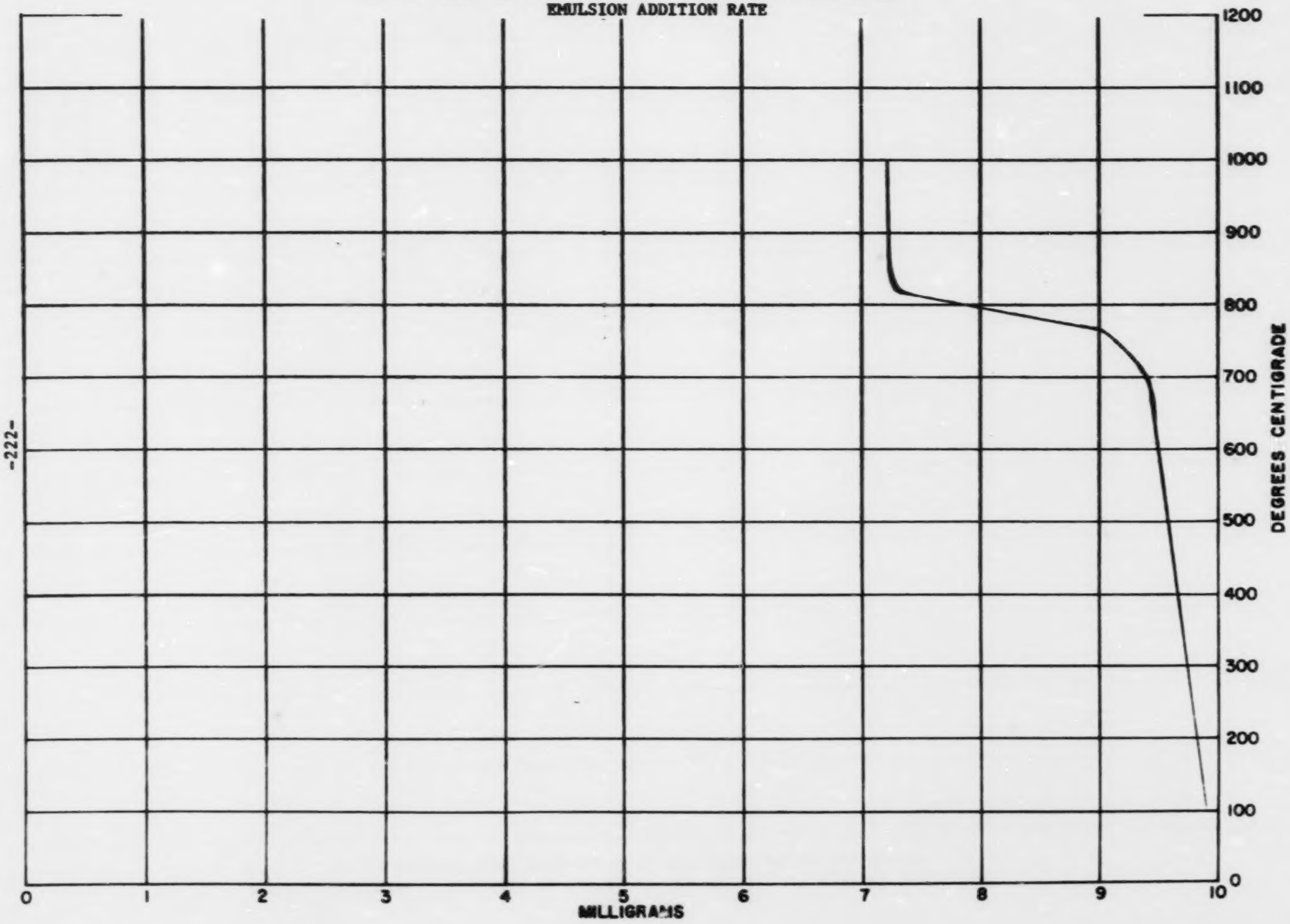


FIGURE 42D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690367 THE 2nd FRACTION CT, 2nd 5 MINUTES OF TEST 85 CONTAINING 26.34 PERCENT LIME FROM A 140.8 PPT EMULSION ADDITION RATE

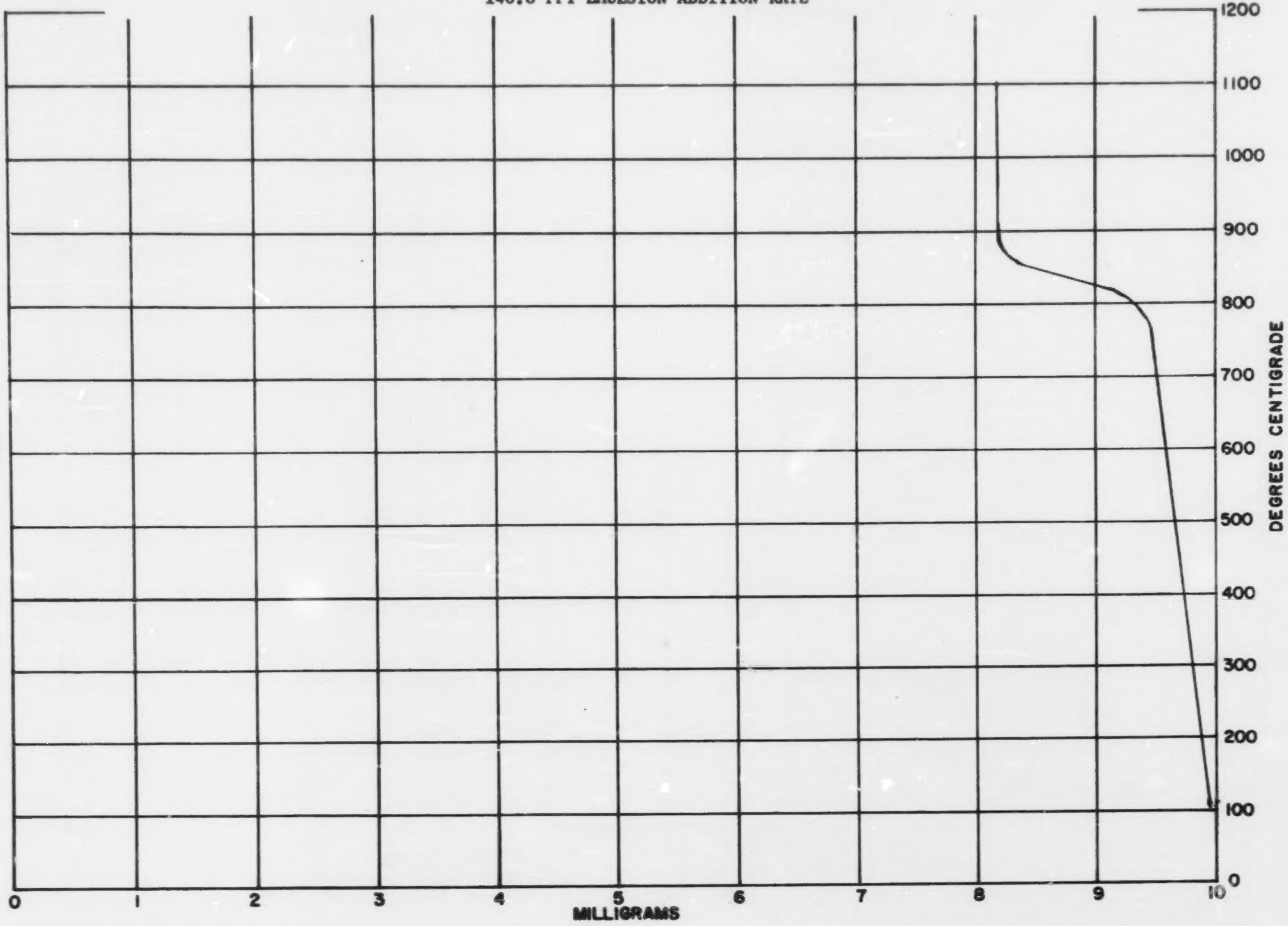


**FIGURE 43D**

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690368 THE CT-2, 2nd 5 MINUTES OF TEST 85 CONTAINING 20.44 PERCENT LIME FROM A 140.8 PPT EMULSION ADDITION RATE

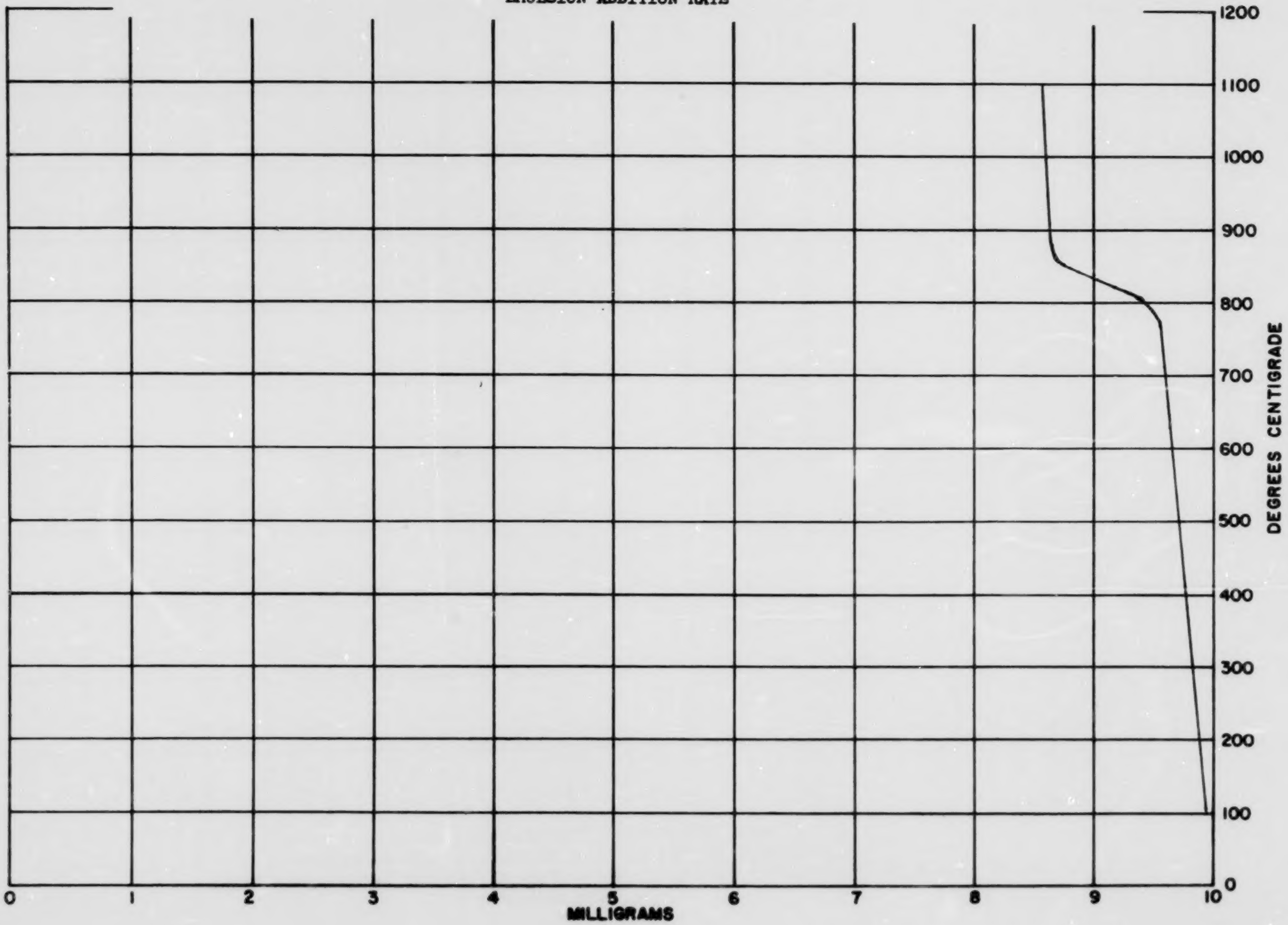


FIGURE 44D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690369 THE CT$_1$, 1st FRACTION 2nd 5 MINUTES RC OF TEST 85 CONTAINING 23.80 PERCENT LIME FROM A 140.8 PPT EMULSION ADDITION RATE

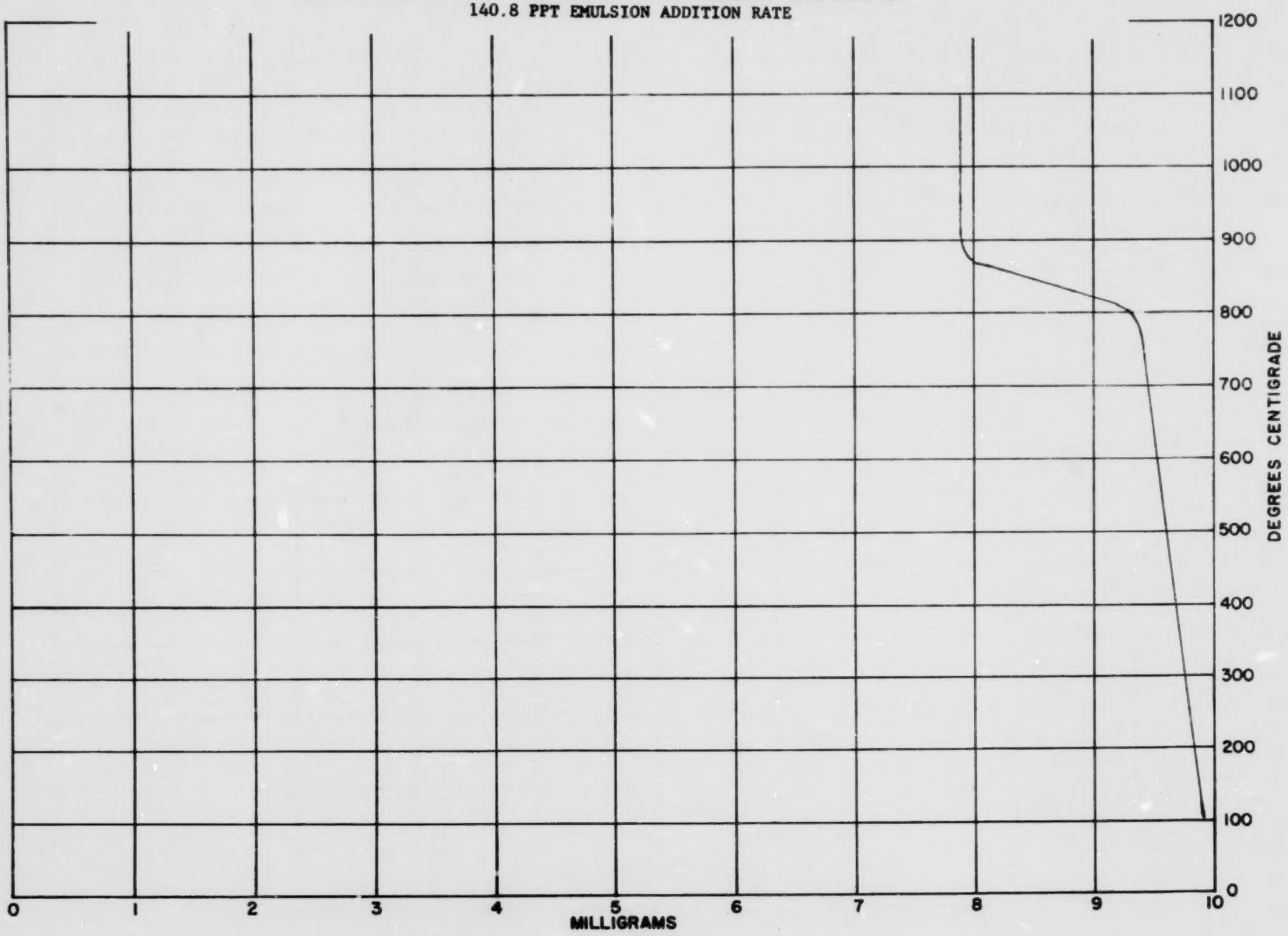


FIGURE 45D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690370 THE CT$_2$, 1st FRACTION 2nd 5 MINUTES RC OF TEST 85 CONTAINING 26.47 PERCENT LIME FROM A 140.8 PPT EMULSION ADDITION RATE

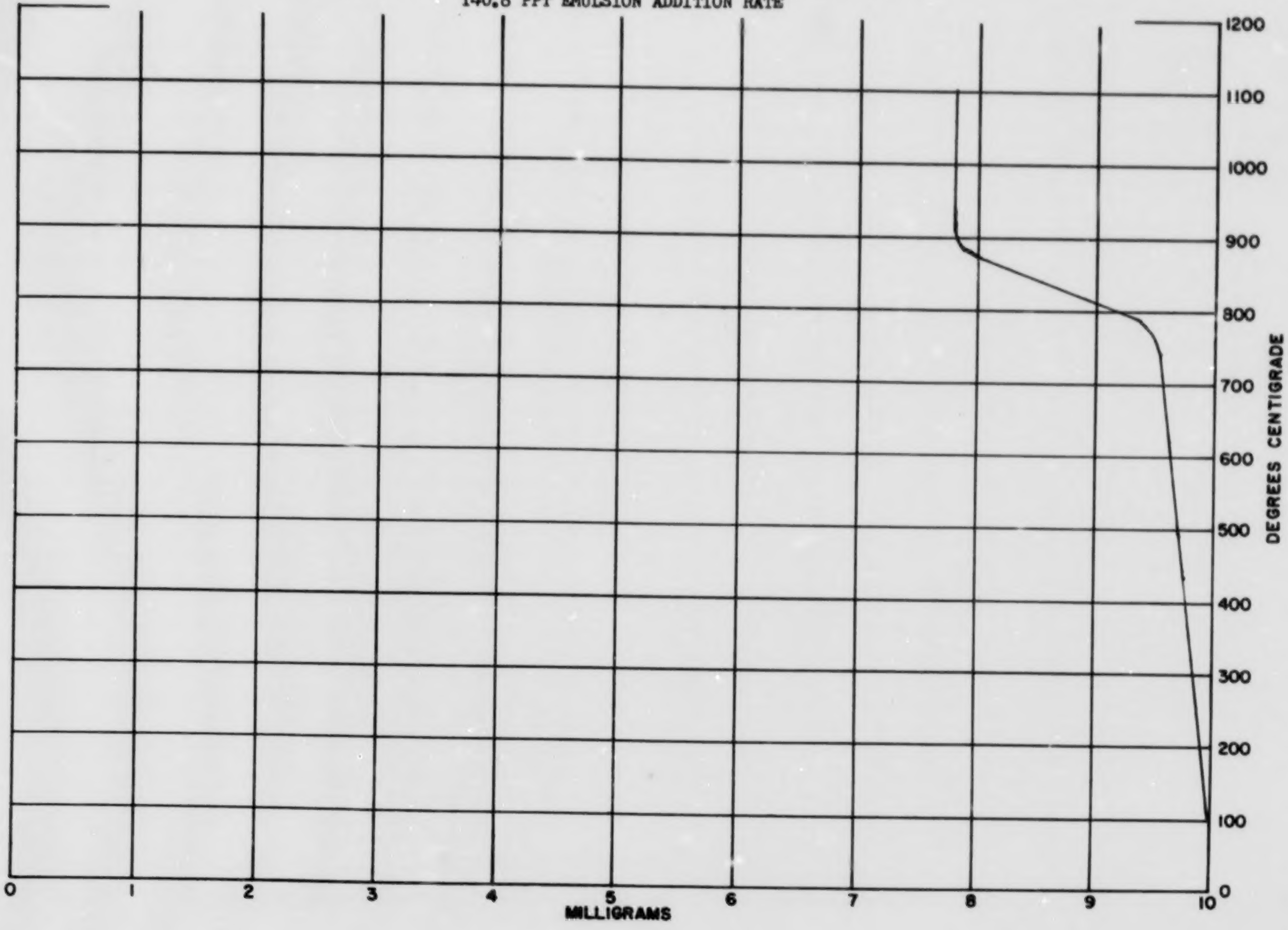


FIGURE 46D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690371 THE CT$_3$, 1st FRACTION 2nd 5 MINUTES RC OF TEST 85 CONTAINING 28.44 PERCENT LIME FROM A 140.8 PPT EMULSION ADDITION RATE

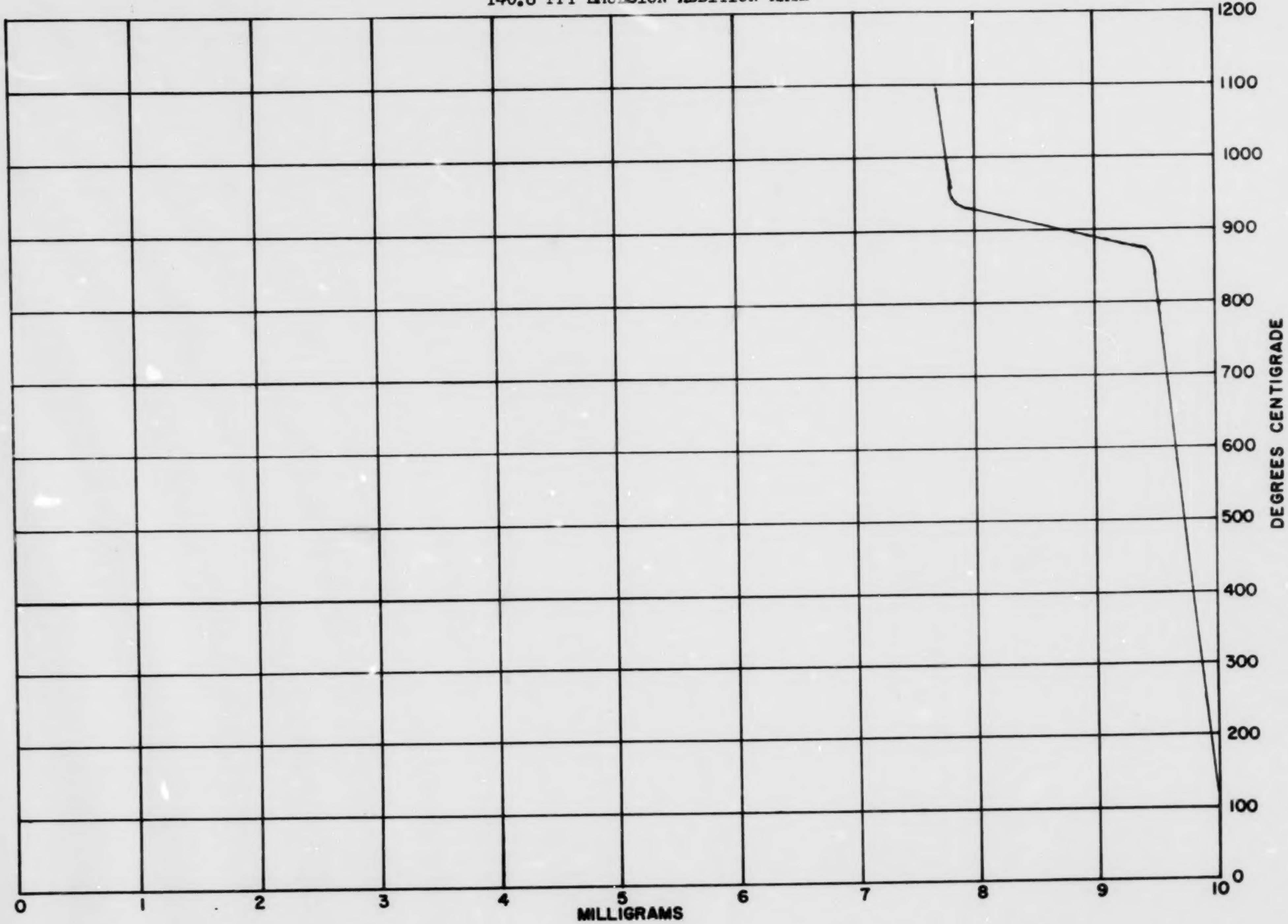


FIGURE 47D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690372 THE CC 3rd, 1st FRACTION 2nd
5 MINUTES RC OF TEST 85 CONTAINING 34.39 PERCENT LIME FROM A
140.8 PPT EMULSION ADDITION RATE

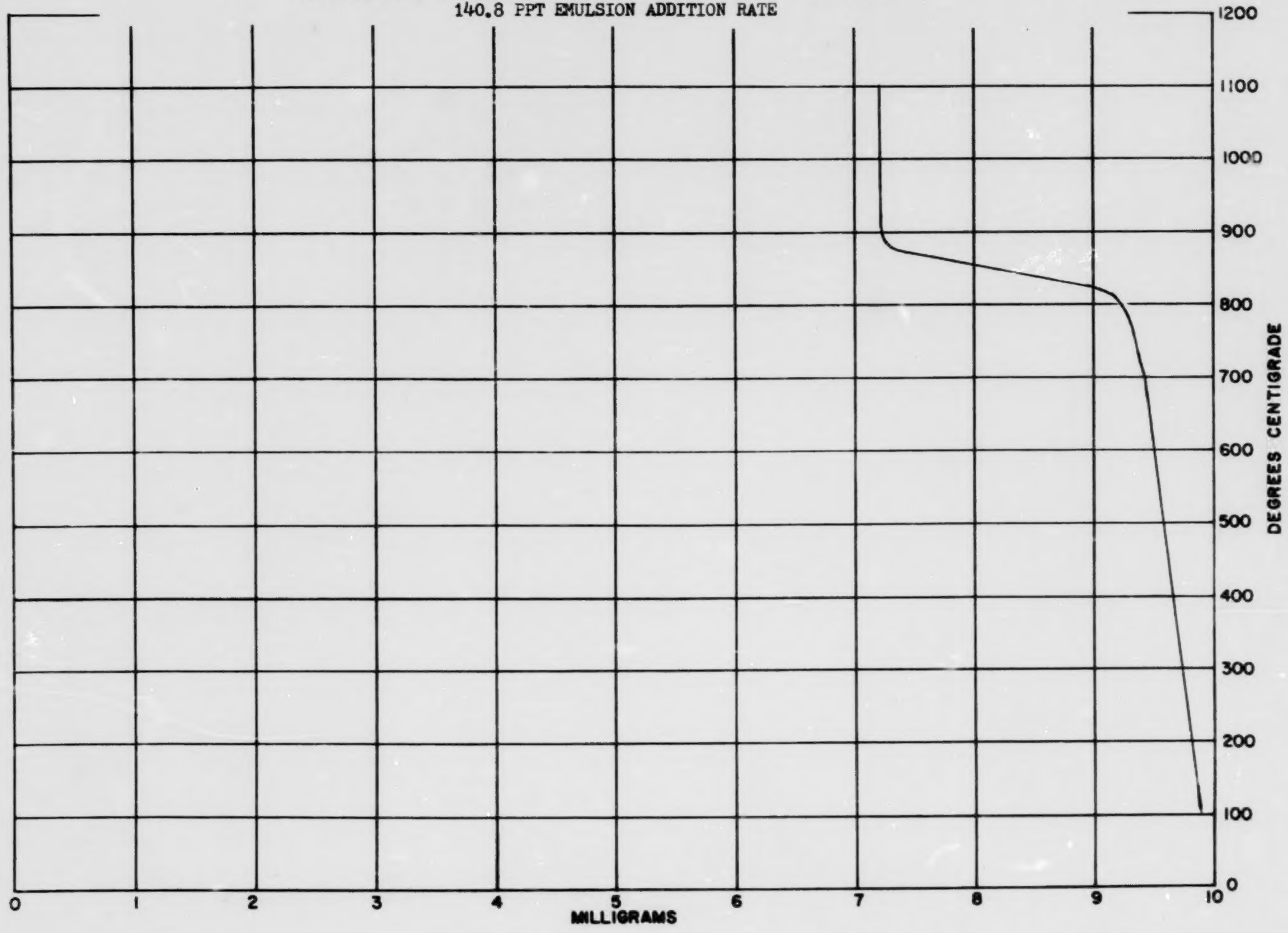


FIGURE 48D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690373 THE $CT_1$, 3rd 5 MINUTES RC OF TEST 85 CONTAINING 19.38 PERCENT LIME FROM A 140.8 PPT EMULSION ADDITION RATE

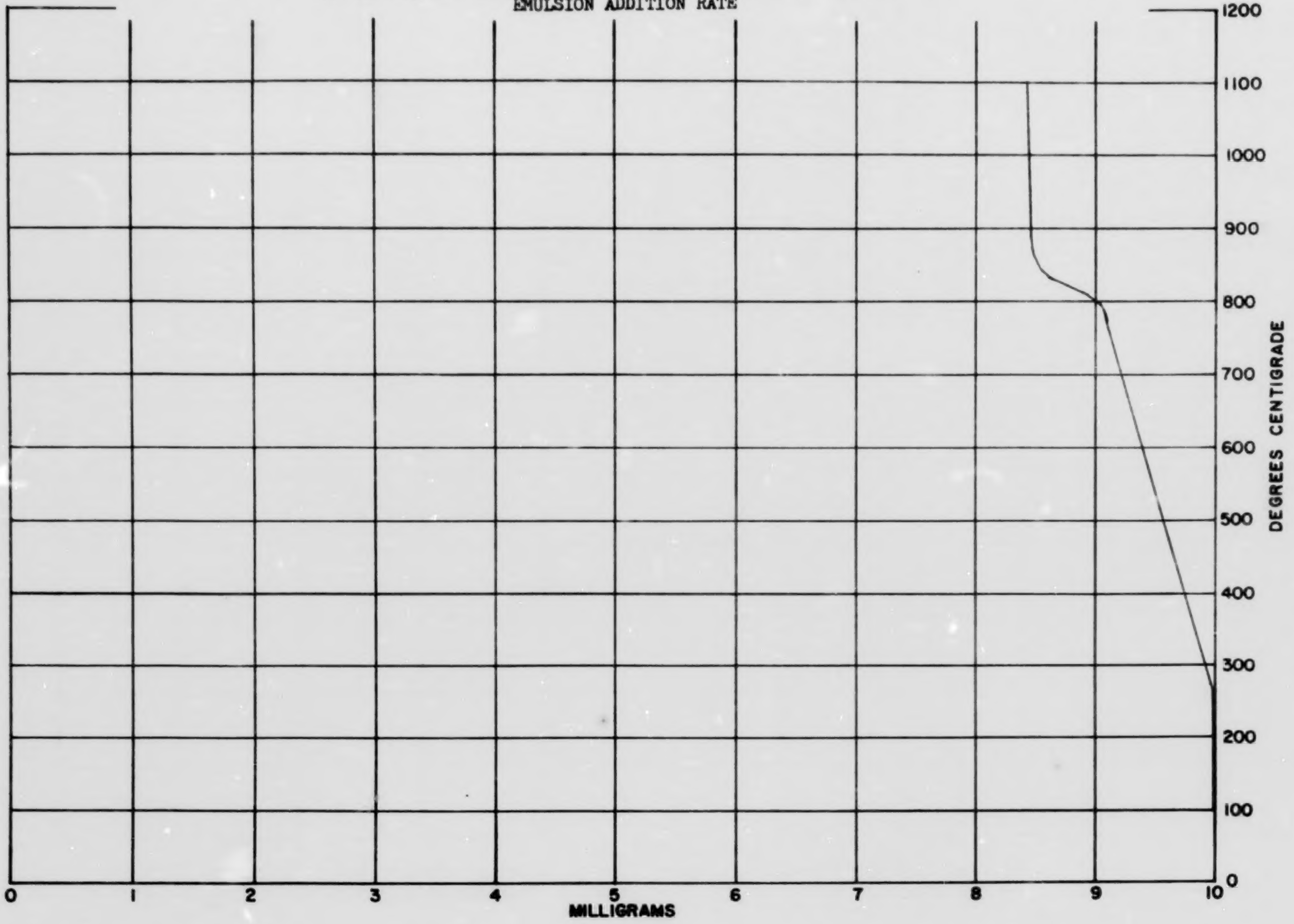


FIGURE 49D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690374 THE $CT_2$, 3rd 5 MINUTES RC OF TEST 85 CONTAINING 18.42 PERCENT LIME FROM A 140.8 PPT EMULSION ADDITION RATE

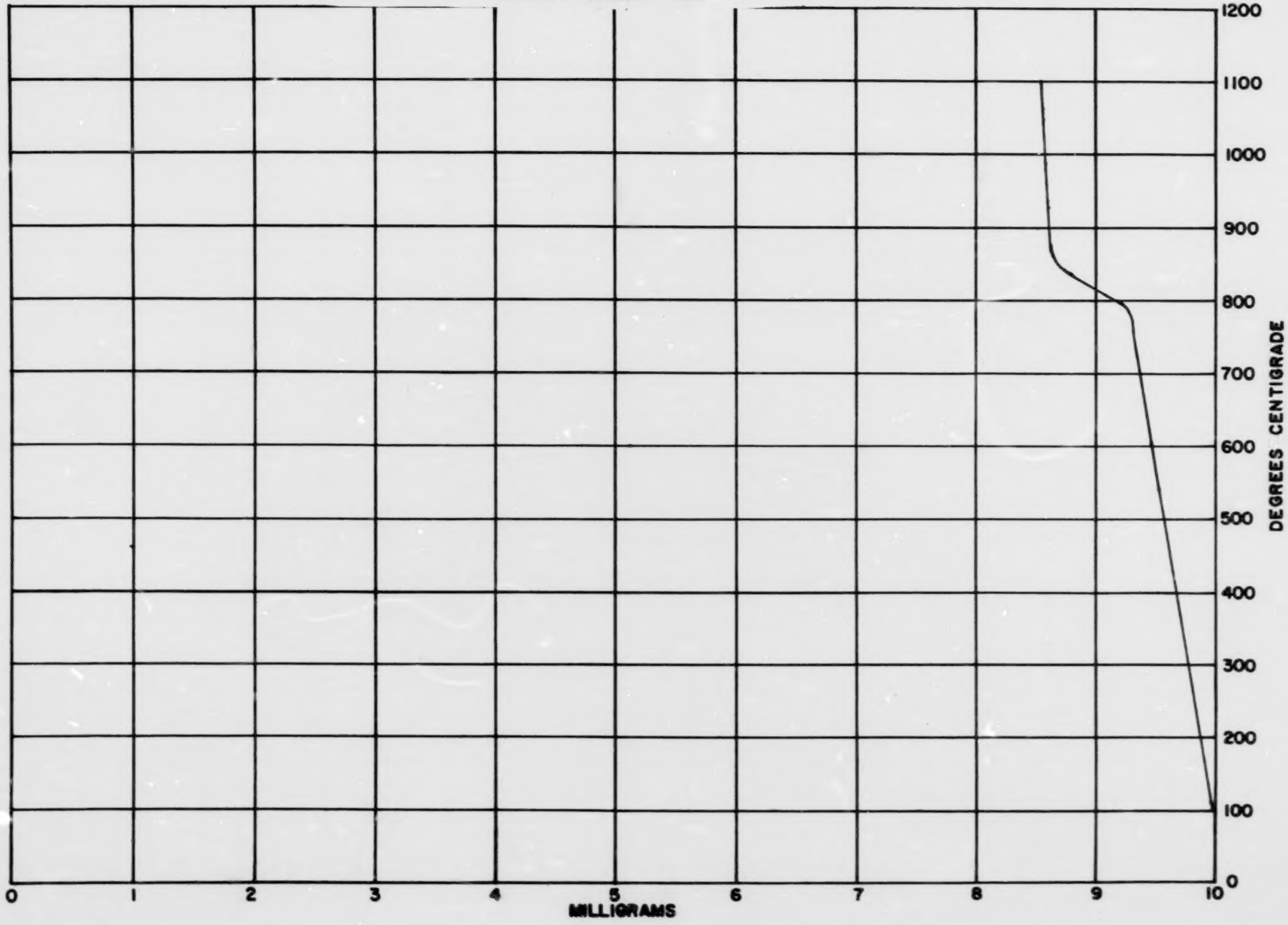


FIGURE 50D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690375 THE $CT_4$, 3rd 5 MINUTES RC
OF TEST 85 CONTAINING 19.21 PERCENT LIME FROM A 140.8 PPT
EMULSION ADDITION RATE

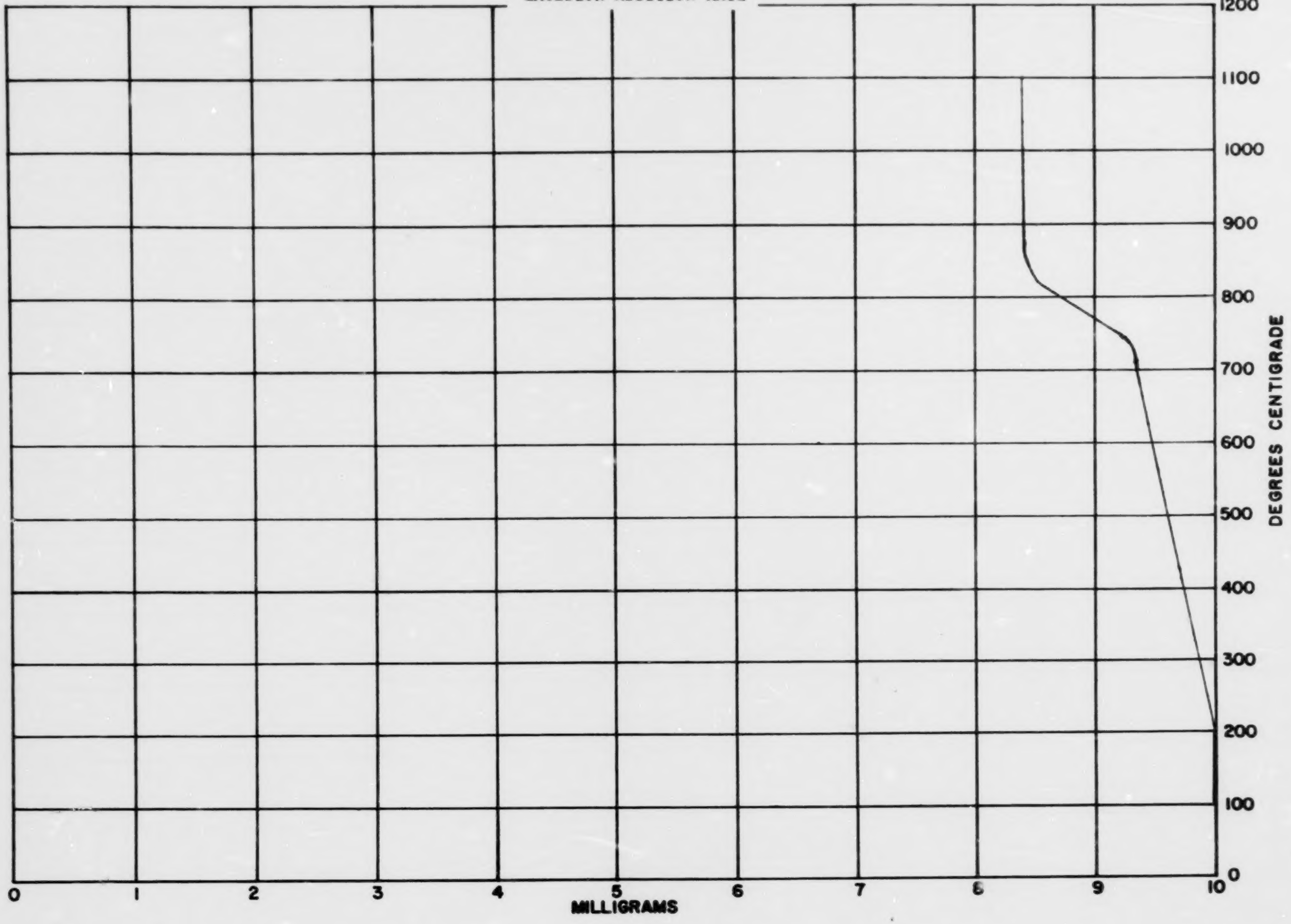
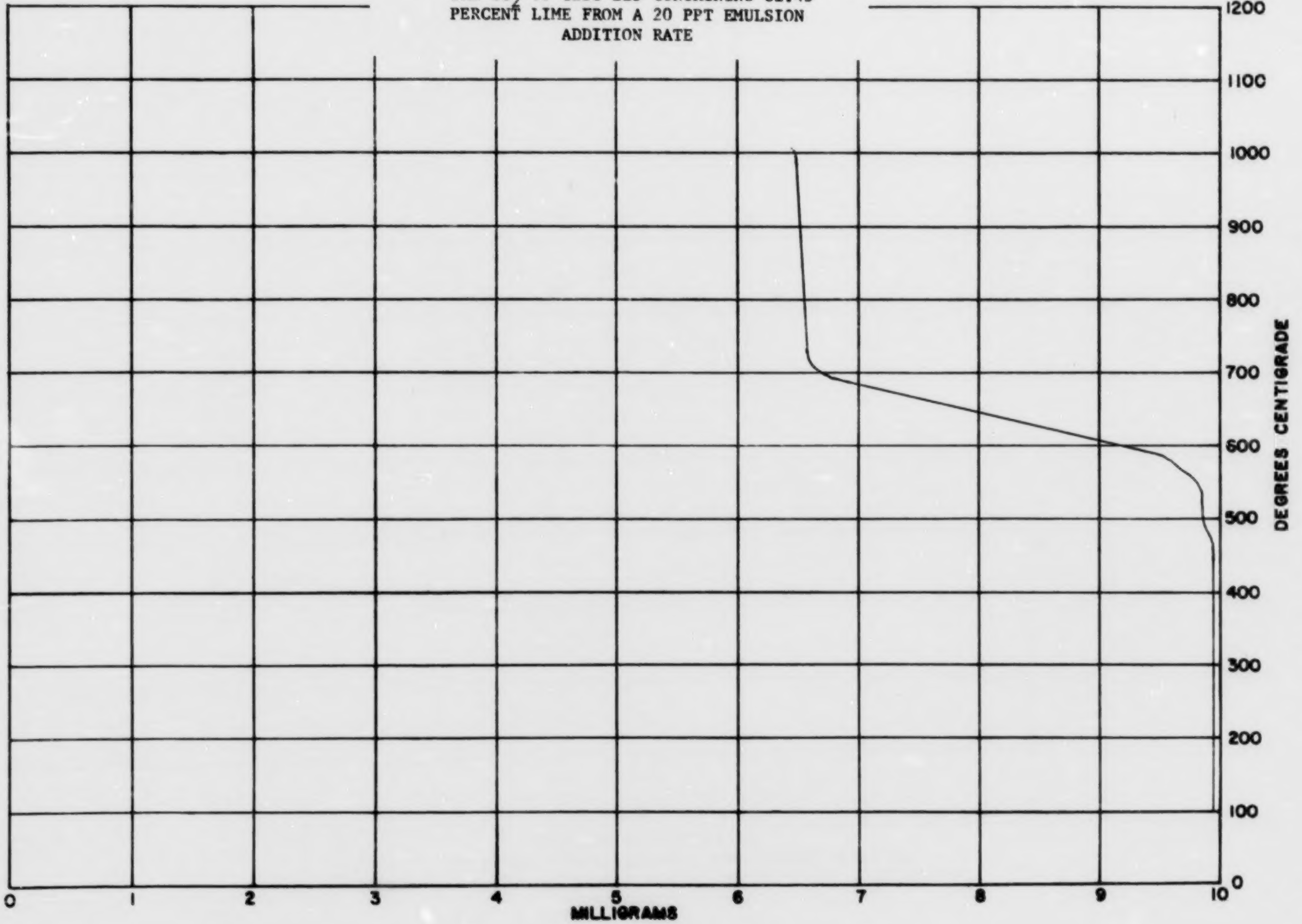


FIGURE 51D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690651
THE $CC_2$ OF TEST 115 CONTAINING 81.45
PERCENT LIME FROM A 20 PPT EMULSION
ADDITION RATE



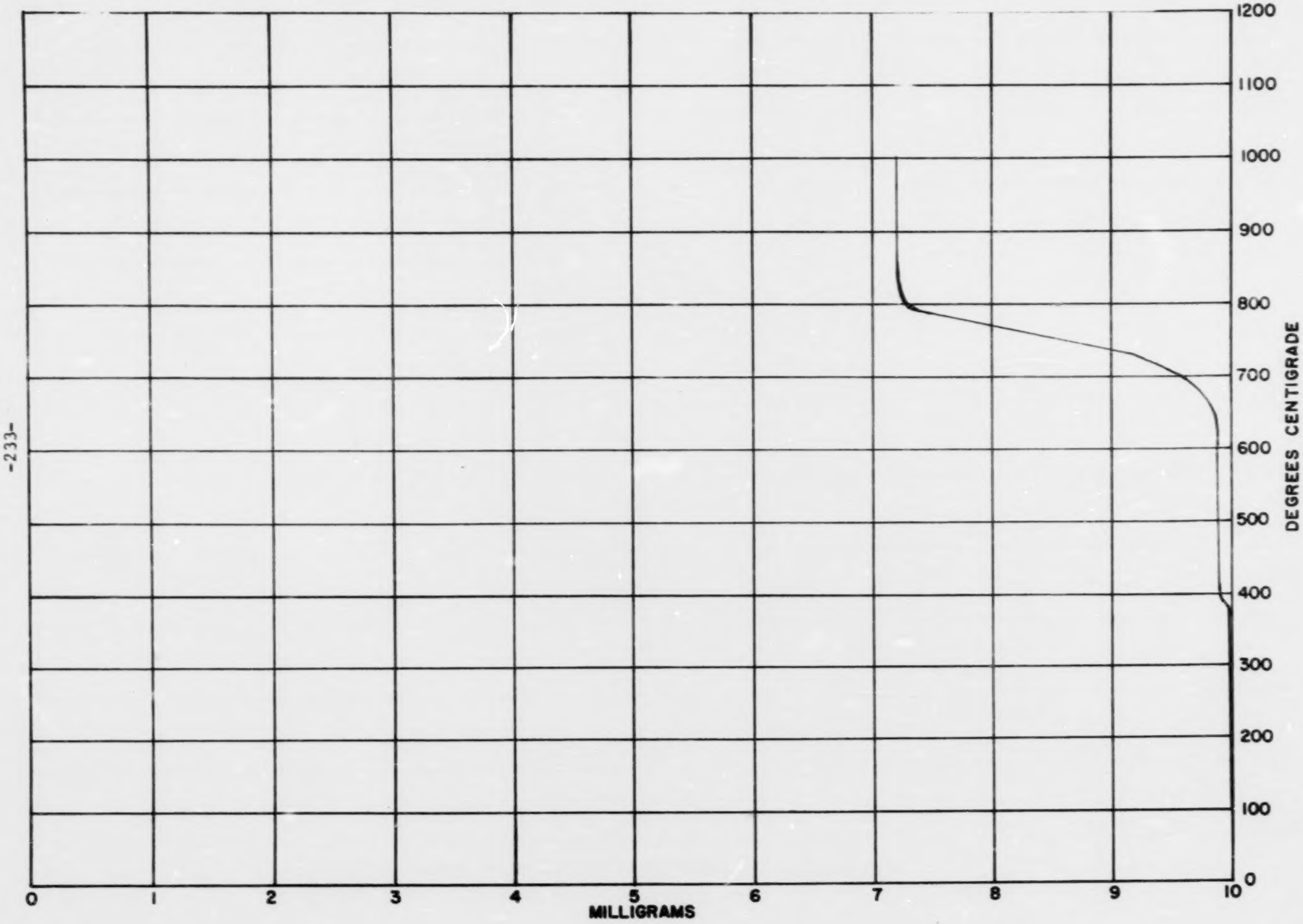


**FIGURE 52D**
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690652 THE SC OF TEST 115 CONTAINING
61.60 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

FIGURE 53D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690653 THE $TT_1$ OF TEST 115 CONTAINING 32.09 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

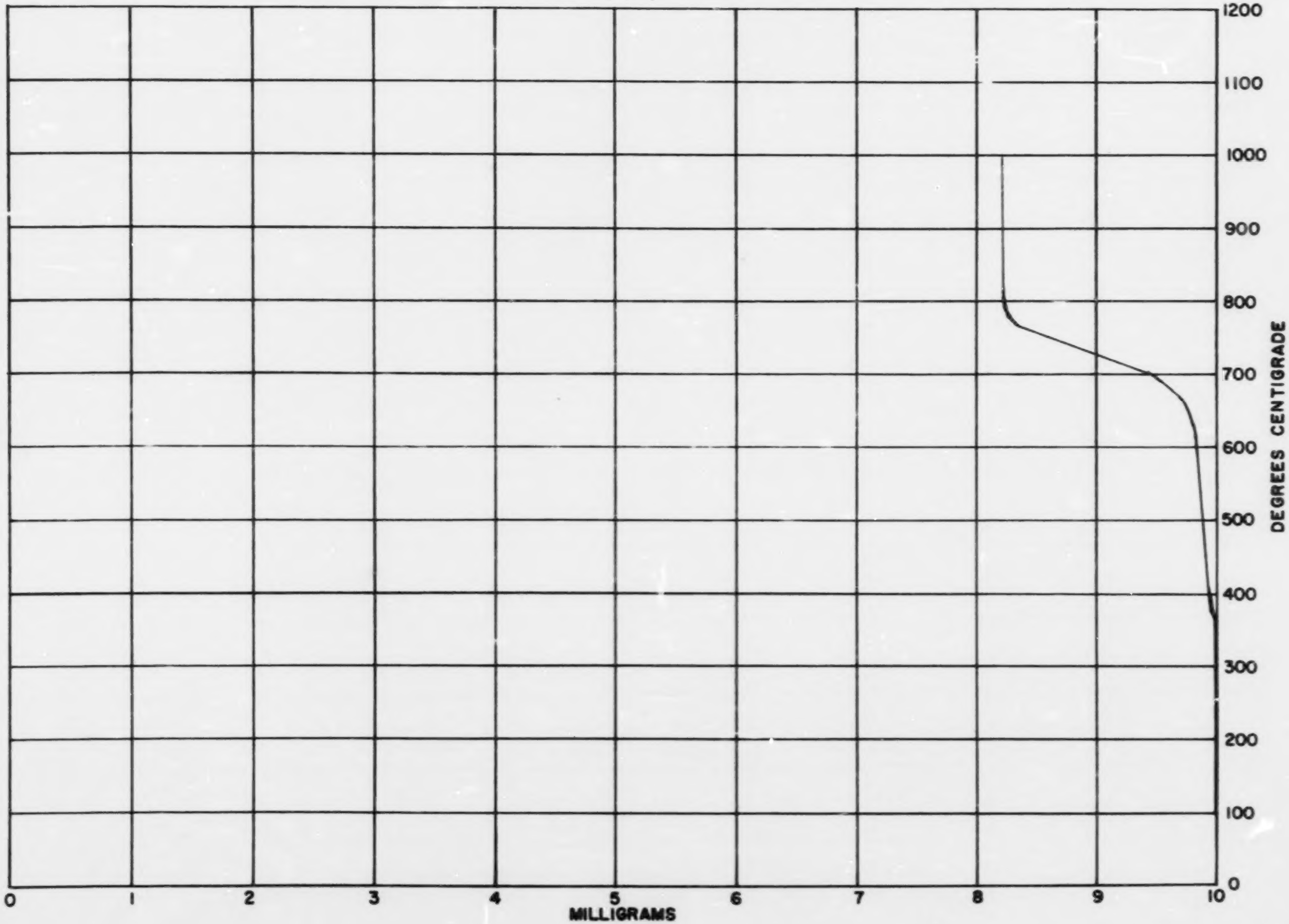


FIGURE 54D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690654
THE $TT_2$ OF TEST 115 CONTAINING 24.35
PERCENT LIME FROM A 20 PPT
EMULSION ADDITION RATE

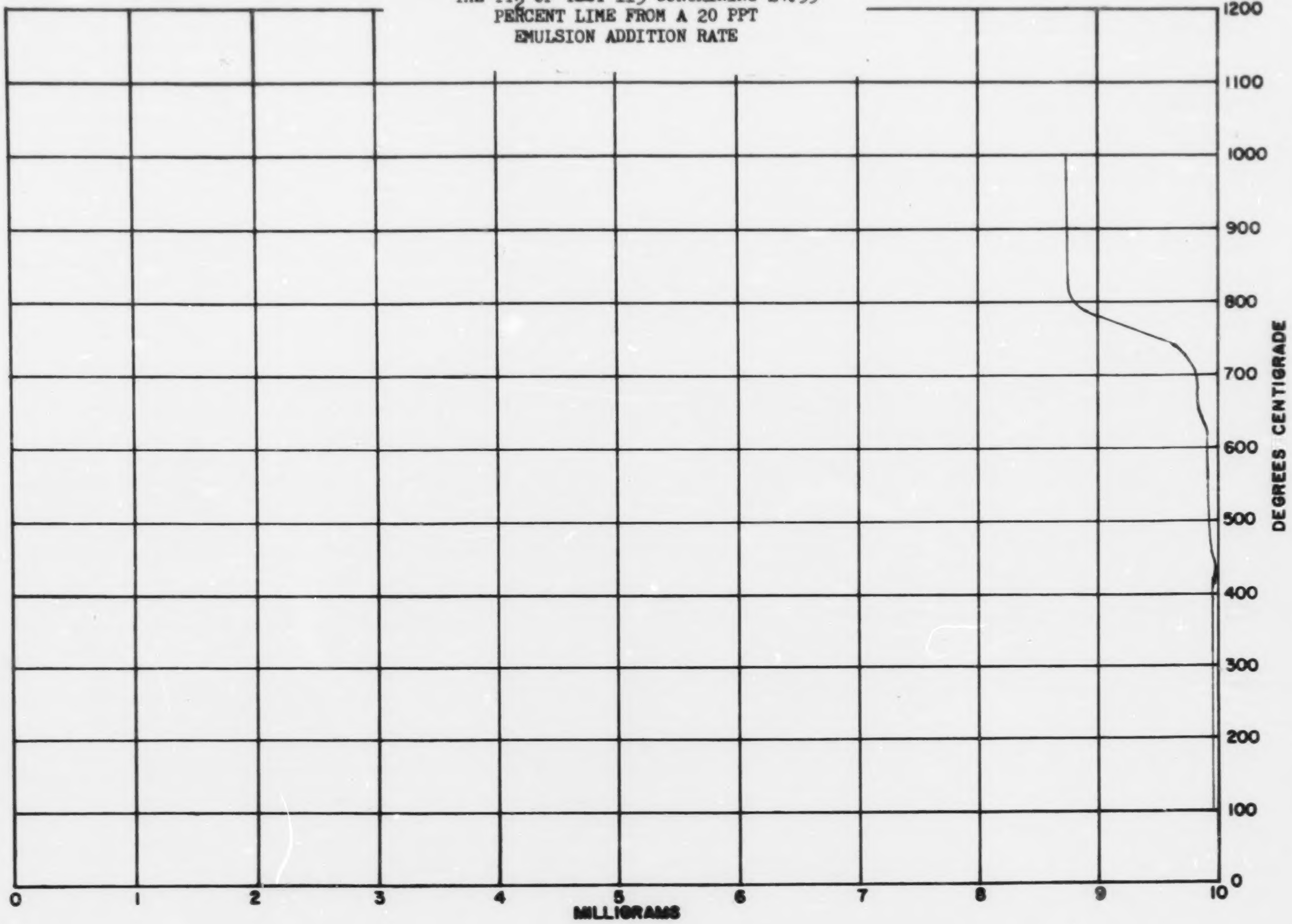


FIGURE 55D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 690655 THE TC$_2$ OF TEST 115 CONTAINING 30.10 PERCENT LIME FROM A 20 PPT EMULSION ADDITION RATE

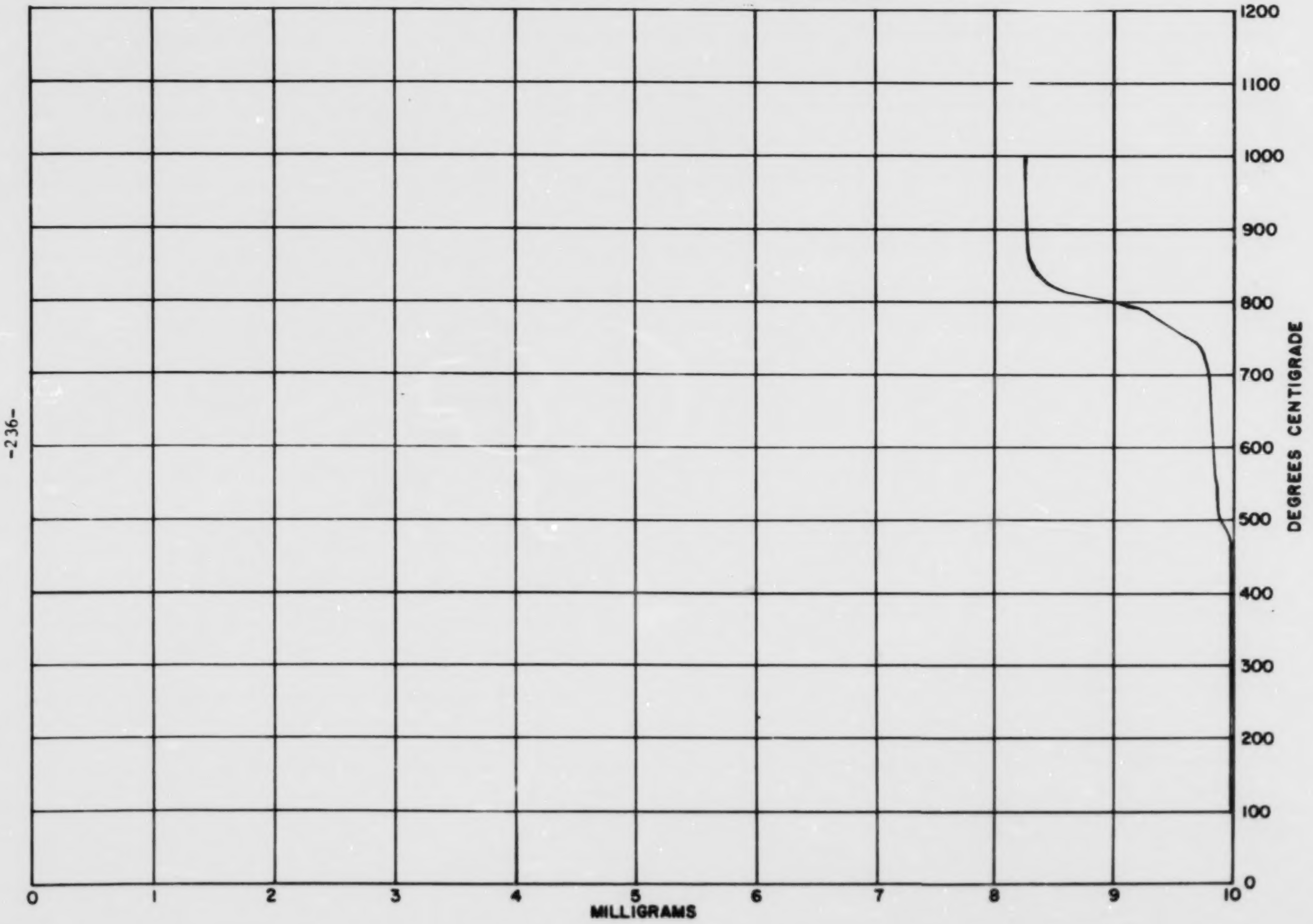


FIGURE 56D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 700071 THE RC$_1$ OF FROTH FLOTATION TEST 124 CONTAINING 47.68 PERCENT LIME AND 1 PPT OF DUOMAC T, 4 PPT OF SODIUM SULFIDE MODIFIER AND AEROFROTH 65 FROTHER

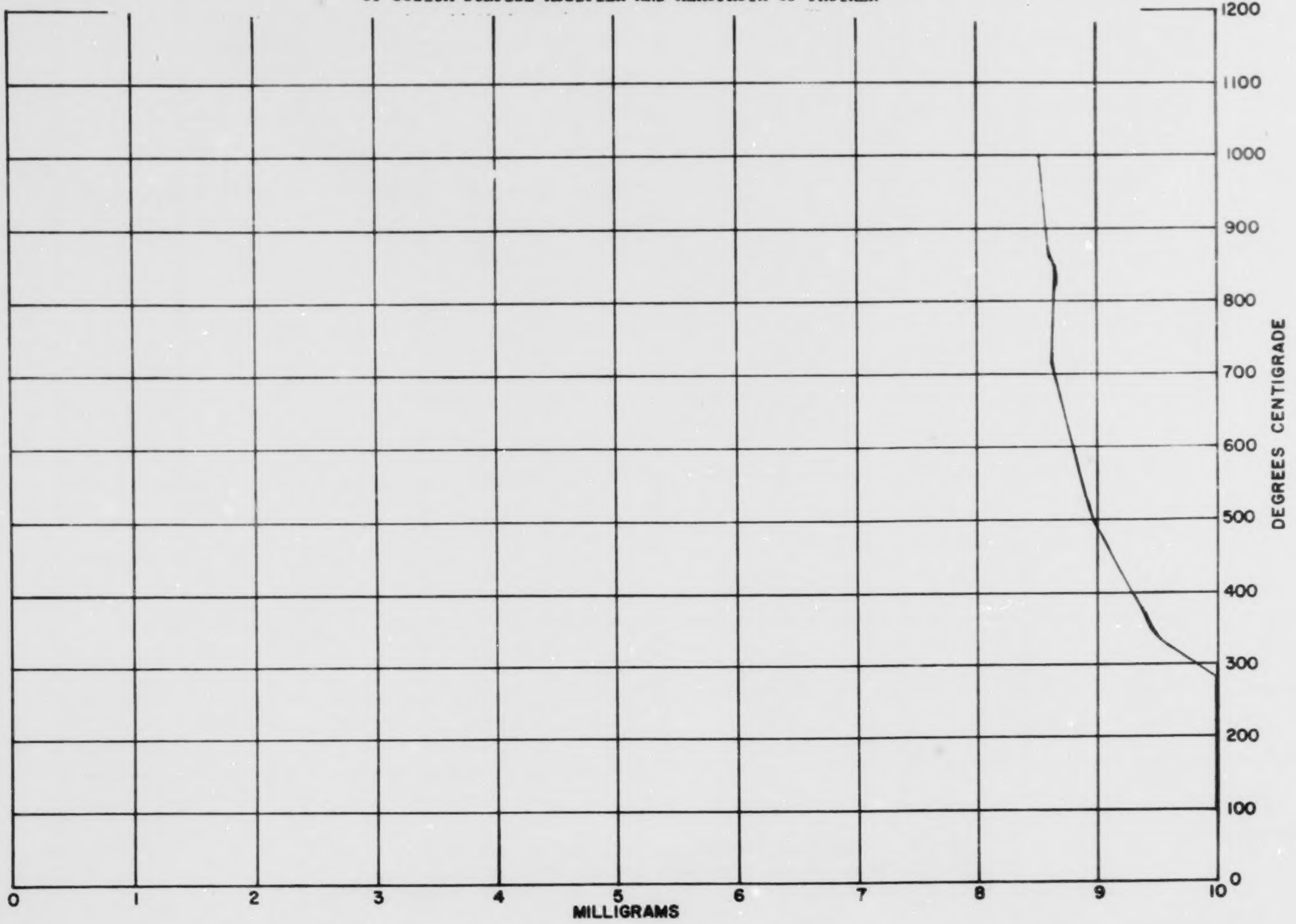


FIGURE 57D
THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 700072 THE RC$_2$ OF FROTH FLOTATION TEST 124 CONTAINING 32.81 PERCENT LIME AND 1 PPT OF DUOMAC T, 4 PPT OF SODIUM SULFIDE AS A MODIFIER AND AEROFROTH 65 FROTHER

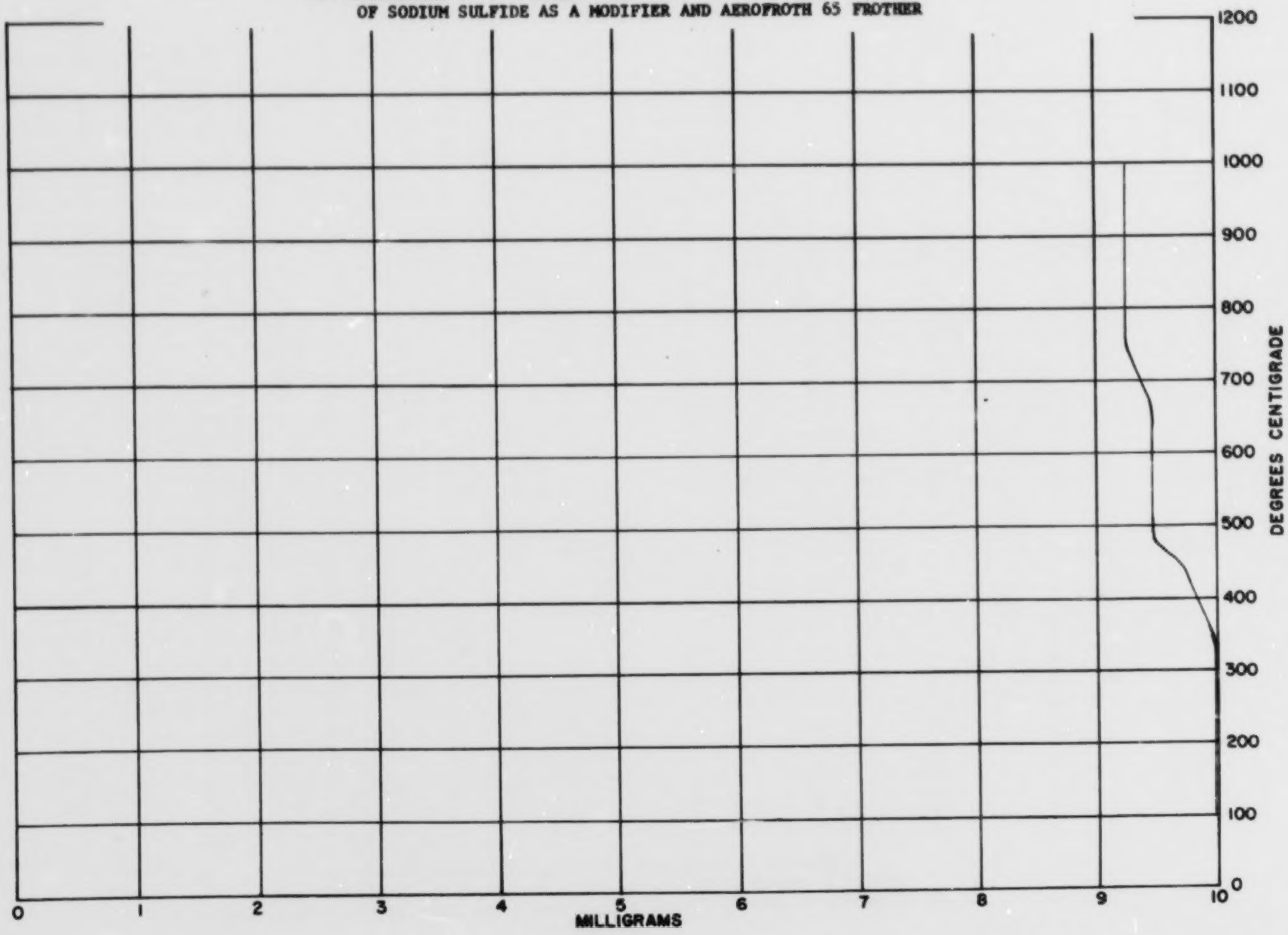
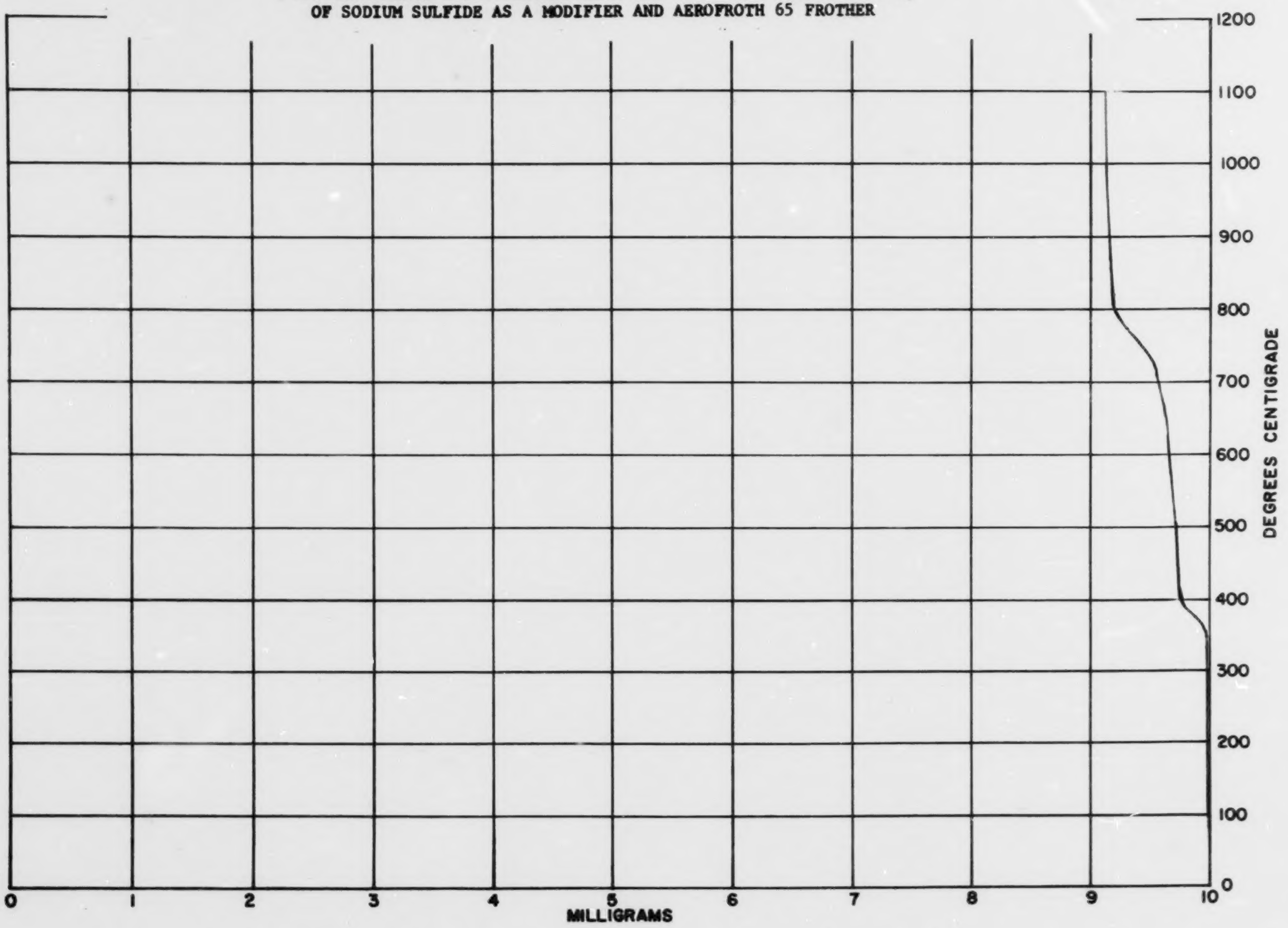


FIGURE 58D

THERMALGRAVIMETRIC ANALYSIS OF SAMPLE 700073 THE RT OF FROTH FLOTATION TEST 124 CONTAINING 28.35 PERCENT LIME AND 1 PPT OF DUOMAC T 4 PPT, OF SODIUM SULFIDE AS A MODIFIER AND AEROFROTH 65 FROTHER



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# APPENDIX E

# AGGLOMERATE SIEVING TEST (AST) DATA

## AST 1E

33% WATER PULP (99 gr.) OF $D_1D_3$ AGITATED IN WARING BLENDOR FOR 1 MIN., ANIONIC EMULSION (50% $H_2O$, 25% FUEL OIL, 22 1/2% TALL OIL AND 2 1/2% SODIUM ALKYLARYLSULFONATE) ADDED AT A RATE OF 90 PPT, STIRRED FOR 5 MIN., POURED INTO 100 MESH SCREEN AND WASHED, $H_2O$ SAVED

| Log. No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Sieve Size |
|---|---|---|---|---|---|
| 690008 | 1.2 | 18.90 | .90 | 0.76 | -325 |
| 690009 | 4.9 | 19.43 | 3.81 | 0.78 | -200 |
| 690010 | 68.0 | 16.37 | 44.63 | 0.66 | -100 |
| 690011 | 10.3 | 16.19 | 6.68 | 0.65 | +100 |

### Water Analysis

| Log No. | Mg.CaO in $H_2O$ | Total Gms. CaO In Solution | Sieve Size |
|---|---|---|---|
| 690001 | 220.08 | | ---- |
| 690002 | 250.38 | | -325 |
| 690003 | 216.92 | 1.35 | -200 |
| 690004 | 576.91 | | -100 |
| 690005 | 98.56 | | +100 |

## AST 2E

33% WATER PULP (99 gr.) OF $D_1D_3$ AGITATED IN WARING BLENDOR FOR 1 MIN., ANIONIC EMULSION (50% $H_2O$, 25% FUEL OIL, 22 1/2% TALL OIL AND 2 1/2% SODIUM ALKYLARYLSULFONATE) ADDED AT A RATE OF 90 PPT, STIRRED FOR 5 MIN., POURED INTO 100 MESH SCREEN AND WASHED, $H_2O$ SAVED, RHEOSTAT USED TO SLOW STIRRING SPEED

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Sieve Size |
|---|---|---|---|---|---|
| 690019 | 7.7 | 16.80 | 5.16 | 0.67 | +100 |
| 690020 | 7.7 | 16.24 | 5.01 | 0.65 | -100 |
| 690021 | 76.8 | 17.59 | 54.53 | 0.71 | -150 |

### Water Analysis

| Log No. | Mg.CaO in $H_2O$ | Total Gms. CaO In Solution | Sieve Size |
|---|---|---|---|
| 690016 | 378.00 | | +100 |
| 690017 | 226.81 | 0.67 | -100 |
| 690018 | 62.44 | | -150 |

## AST 2E

33% WATER PULP (99 gr.) OF $D_1D_3$ AGITATED IN WARING BLENDOR FOR 1 MIN., ANIONIC EMULSION (50% $H_2O$, 25% FUEL OIL, 22 1/2% TALL OIL AND 2 1/2% SODIUM ALKYLARYLSULFONATE) ADDED AT A RATE OF 90 PPT, STIRRED FOR 5 MIN., POURED INTO 100 MESH SCREEN AND WASHED, $H_2O$ SAVED, RHEOSTAT USED TO SLOW STIRRING SPEED

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Sieve Size |
|---|---|---|---|---|---|
| 690019 | 7.7 | 16.80 | 5.16 | 0.67 | +100 |
| 690020 | 7.7 | 16.24 | 5.01 | 0.65 | -100 |
| 690021 | 76.8 | 17.59 | 54.53 | 0.71 | -150 |

### Water Analysis

| Log No. | Mg.CaO in $H_2O$ | Total Gms. CaO In Solution | Sieve Size |
|---|---|---|---|
| 690016 | 378.00 | 0.67 | +100 |
| 690017 | 226.81 | | -100 |
| 690018 | 62.44 | | -150 |

## AST 3E

33% WATER PULP (99 gr.) OF $D_1D_2$ AGITATED IN WARING BLENDOR FOR 1 MIN., ANIONIC EMULSION (50% $H_2O$, 25% FUEL OIL, 22 1/2% TALL OIL AND 2 1/2% SODIUM ALKYLARYLSULFONATE) ADDED AT A RATE OF 90 PPT, STIRRED FOR 5 MIN., POURED INTO 100 MESH SCREEN AND WASHED, $H_2O$ SAVED, RHEOSTAT USED TO SLOW STIRRING SPEED

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Sieve Size |
|---|---|---|---|---|---|
| 690025 | 4.8 | 23.80 | 5.04 | 1.05 | +100 |
| 690026 | 70.7 | 18.90 | 58.68 | 0.83 | -150 |
| 690027 | 7.4 | 17.41 | 5.70 | 0.77 | -100 |

### Water Analysis

| Log No. | Mg.CaO in $H_2O$ | Total Gms. CaO In Solution | Sieve Size |
|---|---|---|---|
| 690022 | 540.40 |  | +100 |
| 690023 | 1316.00 | 1.96 - 8.69% | -150 |
| 690024 | 105.84 |  | -100 |

### AST 4E

33% WATER PULP (99 gr.) OF PID AGITATED IN WARING BLENDOR FOR 2 MIN., AT 6000 RPM, ANIONIC EMULSION (50% $H_2O$, 25% FUEL OIL, 22 1/2% TALL OIL AND 2 1/2% SODIUM ALKYLARYLSULFONATE) ADDED AT A RATE OF 90 PPT, STIRRED FOR 5 MIN., POURED INTO 100 MESH SCREEN

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Sieve Size |
|---|---|---|---|---|---|
| 690030 | 19.7 | 26.39 | 17.34 | 0.88 | +150 |
| 690031 | 22.5 | 29.49 | 22.28 | 0.99 | -150 B.W.* |
| 690031 | 51.5 | 30.63 | 52.53 | 1.02 | -150 A.W.* |

*B.W. - Before Water Wash
*A.W. - After Water Wash

### AST 5E

33% WATER PULP (99 gr.) OF PID AGITATED IN WARING BLENDOR FOR 2 MIN., AT 6000 RPM, ANIONIC EMULSION (50% $H_2O$, 25% FUEL OIL, 22 1/2% TALL OIL AND 2 1/2% SODIUM ALKYLARYLSULFONATE) ADDED AT A RATE OF 90 PPT, STIRRED FOR 5 MIN., POURED INTO 150 MESH SCREEN AND WASHED

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Sieve Size |
|---|---|---|---|---|---|
| 690061 | 9.0 | 23.37 | 7.19 | 0.78 | +150 |
| 690062 | 60.0 | 30.02 | 61.69 | 1.01 | -150 B.W. |
| 690063 | 29.0 | 28.84 | 28.63 | 0.97 | -150 A.W. |

AST 6E

33% WATER PULP (99 gr.) OF $D_1D_3$ AGITATED IN WARING BLENDOR FOR 2 MIN., AT 6000 RPM, ANIONIC EMULSION (50% $H_2O$, 25% FUEL OIL, 22 1/2% TALL OIL AND 2 1/2% SODIUM ALKYLARYLSULFONATE) ADDED AT A RATE OF 90 PPT, STIRRED FOR 5 MIN., POURED INTO 150 MESH SCREEN

TEST ABORTED

DID NOT AGGLOMERATE

## AST 7E

33% WATER PULP (99 gr.) OF $D_1D_2$ AGITATED IN WARING BLENDOR FOR 2 MIN., AT 6000 RPM, ANIONIC EMULSION (50% $H_2O$, 25% FUEL OIL, 22 1/2% TALL OIL AND 2 1/2% SODIUM ALKYLARYLSULFONATE) ADDED AT A RATE OF 90 PPT, STIRRED FOR 5 MIN., POURED INTO 150 MESH SCREEN

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Sieve Size |
|---|---|---|---|---|---|
| 690064 | 75.0 | 26.04 | 97.31 | 1.15 | +150 |
| 690065 | 4.0 | 29.97 | 5.97 | 1.32 | -150 B.W. |
| 690066 | 10.0 | 30.28 | 15.09 | 1.34 | -150 A.W. |

## AST 8E

33% WATER PULP (99 gms.) OF $D_1D_3$ AGITATED IN A WARING BLENDOR, 10 DROPS 0.05% CALGON 240 ADDED, ANIONIC EMULSION (50% $H_2O$, 25% FUEL OIL, 22 1/2% TALL OIL AND 2 1/2% SODIUM ALKYLARYLSULFONATE) ADDED AT A RATE OF 90 PPT, ROTOR SPEED BETWEEN 3000 AND 7000 RPM

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690043 | 44.0 | 28.22 | 49.20 | 1.25 | +150 |
| 690044 | 32.0 | 32.64 | 41.62 | 1.45 | -150 B.W. |
| 690045 | 31.0 | 31.60 | 38.74 | 1.40 | -150 A.W. |

## AST 9E

33% WATER PULP (99 gms.) OF $D_1D_3$ AGITATED IN A WARING BLENDOR, 10 DROPS 0.05% CALGON 240 ADDED, ANIONIC EMULSION (50% $H_2O$, 25% FUEL OIL, 22 1/2% TALL OIL AND 2 1/2% SODIUM ALKYLARYLSULFONATE) ADDED AT A RATE OF 90 LBS/TON, ROTOR SPEED BETWEEN 3000 AND 7000 RPM

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690046 | 80.0 | 21.26 | 75.43 | 0.94 | +150 |
| 690047 | 3.0 | 23.30 | 3.10 | 1.03 | -150 B.W. |
| 690048 | 17.0 | 20.44 | 15.38 | 0.91 | -150 A.W. |

## AST 10E

33% WATER PULP (99 gms.) OF PID AGITATED IN A WARING BLENDOR, 10 DROPS 0.05% CALGON 240 ADDED, ANIONIC EMULSION (50% $H_2O$, 25% FUEL OIL, 22 1/2% TALL OIL AND 2 1/2% SODIUM ALKYLARYLSULFONATE) ADDED AT A RATE OF 90 PPT, ROTOR SPEED BETWEEN 3000 AND 7000 RPM

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690049 | 57.0 | 25.03 | 45.19 | 0.84 | +150 |
| 690050 | 17.0 | 28.48 | 15.32 | 0.96 | -150 B.W. |
| 690051 | 32.0 | 28.86 | 26.15 | 0.87 | -150 A.W |

## AST 11E

33% WATER PULP (99 gms.) OF PID AGITATED IN A WARING BLENDOR, 10 DROPS 0.05% CALGON 240 ADDED, ANIONIC EMULSION (50% $H_2O$-50% FUEL OIL) ADDED AT A RATE OF 90 PPT, ROTOR SPEED BETWEEN 3000 AND 7000 RPM

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690055 | 7.0 | 18.38 | 4.04 | 0.62 | +150 |
| 690056 | 85.0 | 28.44 | 75.82 | 0.95 | -150 B.W. |
| 690057 | 15.0 | 27.57 | 12.98 | 0.93 | -150 A.W. |

## AST 12E

33% WATER PULP (99 gms.) OF PID AGITATED IN A WARING BLENDOR, 10 DROPS 0.05% CALGON 240 ADDED, EMULSION (50% FUEL OIL-50% TALL OIL) ADDED AT A RATE OF 90 PPT, ROTOR SPEED BETWEEN 3000 and 7000 RPM

| Log. No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690052 | 50.0 | 23.76 | 38.71 | 0.80 | +150 |
| 690053 | 6.0 | 30.72 | 5.99 | 1.03 | -150 B.W. |
| 690054 | 47.0 | 26.03 | 39.85 | 0.87 | -150 A.W. |

AST 13E

33% WATER PULP (99 gr.) of PID AGITATED IN A WARING BLENDOR, 10 DROPS OF CONCENTRATED HCl ADDED, EMULSION (50% FUEL OIL-50% TALL OIL) ADDED AT A RATE OF 90 PPT, ROTOR SPEED BETWEEN 3000 and 7000 RPM

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690069 | 2.0 | 16.54 | 0.95 | 0.56 | +150 |
| 690070 | 104.0 | 28.31 | 85.19 | 0.95 | -150 B.W. |
| 690071 | 10.0 | 24.81 | 7.17 | 0.83 | -150 A.W. |

## AST 14E

33% WATER PULP (100 gr.) $D_1D_2$ AGITATED IN A WARING BLENDOR, ADDED 10 DROPS OF CONCENTRATED HCl, ADDED 50% FUEL OIL, 50% TALL OIL EMULSION AT 90 PPT, ROTOR SPEED 6000 RPM

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690067 | 75.0 | 26.95 | 87.01 | 1.20 | +150 |
| 690068 | 5.0 | 34.56 | 7.44 | 1.53 | -150 B.W. |
| 690058 | 23.0 | 29.27 | 28.97 | 1.30 | -150 A.W. |

## AST 15E

33% WATER PULP (100 gr.) $D_1D_3$ AGITATED IN WARING BLENDOR, ADDED 10 DROPS OF CONCENTRATED HCl, ADDED 50% FUEL OIL, 50% TALL OIL EMULSION, ROTOR SPEED 6000 RPM

Test Aborted

Not Submitted for Chemical Analysis

### AST 16E

33% WATER PULP (100 gr.) PID AGITATED IN WARING BLENDOR, ADDED 10 DROPS OF SODIUM SILICATE, ADDED 50% FUEL OIL, 50% TALL OIL EMULSION, ROTOR SPEED 6000 RPM

| Log No. | Wt. Rec. Gms. | Grade Percent Ca0 | Percent Ca0 Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690091 | 2.0 | 21.84 | 1.58 | 0.73 | +150 |
| 690092 | 98.0 | 28.04 | 97.40 | 0.94 | -150 B.W. |
| 690093 | 12.0 | 27.44 | 11.24 | 0.92 | -140 A.W. |

AST 17E

33% WATER PULP (150 gr.) $D_1D_2$ AGITATED IN WARING BLENDOR, 10 DROPS OF SODIUM SILICATE ADDED, ADDED 50% FUEL OIL, 50% TALL OIL EMULSION, ROTOR SPEED 6000 RPM FOR 3 MIN.

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690128 | 12.0 | Not Submitted for Chemical Analysis | | | +150 |
| 690127 | 141.0 | | | | -150 B.W. |

## AST 18E

150 GR. PID AND 50 GR. TALL OIL GROUND IN A BALL MILL, AGITATED IN WARING BLENDOR AND TAKEN AS MATERIAL FLOATING, STUCK TO SIDES AND THAT IN THE WATER

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690131 | 0.9 | Test Aborted Not Submitted For Chemical Analysis | | | Water |
| 690132 | 197.0 | | | | Solids |

## AST 19E

150 GR. OF PID GROUND IN BALL MILL WITH 1.0 GR. TALL OIL,
TRANSFERRED TO WARING BLENDOR AND AGITATED, FRACTIONS TAKEN WERE THOSE FLOATING,
STUCK ON SIDES OF BALL AND THOSE IN WATER

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690133 | 9.1 | Test Aborted Not Submitted For Chemical | | | Sides |
| 690134 | 1.6 | Analysis | | | Water |
| 690135 | 20.1 | | | | Float |

### AST 20E

### 33% WATER SLURRY, 100 GR. PID AGITATED IN WARING BLENDOR WITH 3 DROPS TALL OIL, 6000 RPM FOR 3 MIN.

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690136 | 24.7 | | | | Sides |
| 690137 | 3.0 | 28.95 | | 0.97 | Float |
| 690138 | 1.7 | 70.21 | | 2.35 | Water |

## AST 21E

33% WATER SLURRY, 100 GR. PID AGITATED IN WARING BLENDOR WITH 6 DROPS TALL OIL, 6000 RPM FOR 3 MIN.

| Log No. | Wt. Rec. Gms. | Grade Percent CaO | Percent CaO Rec. | Ratio of Enrichment | Screen Size |
|---|---|---|---|---|---|
| 690139 | 39.7 | 27.35 | | 0.91 | AST 21 Sides |
| 690140 | 1.3 | 27.74 | | 0.93 | AST 21 Float |